Radio-teleph... for everyone

Laurence Marsham Cockaday

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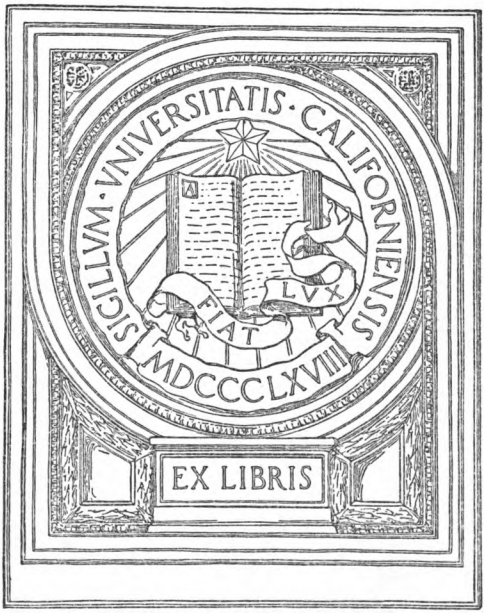

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The author in his laboratory at work on apparatus for transmitting music.

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RADIO-TELEPHONY FOR EVERYONE

THE WIRELESS: HOW TO CONSTRUCT AND MAINTAIN MODERN TRANSMITTING AND RECEIVING APPARATUS

BY

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FOREWORD

Since the advent of the radiophone as an educational as well as entertaining asset to the comforts and conveniences of the home, there has been an increasing need of literature on the subject, written in "everyman's language" with the sole idea of dispelling the shroud of mystery surrounding radio in the layman's mind.

The author has therefore accepted the task of writing a simple explanation of the working theory of radio in general, and the radiophone transmitter and receiver in particular, so that the boy of sixteen and the man of sixty will read it with equal interest and satisfaction. The work will deal in detail with the different types of receiving sets, antenna construction, data on crystal and vacuum tube detectors, and the care of apparatus; in fact, all the data necessary to install and keep in operation a modern radiophone.

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INTRODUCTION

In the latter half of the nineteenth century Hertz began his all-important experiments with high voltage sparks which finally culminated in his discovery of the vibration or wave through space which occurred when these sparks took place. These waves through the ether now bear his name. Hertzian waves, they are called, and it is by their use that radio is made possible.

Marconi, a very brilliant young man, was much interested in the work that Hertz had been doing, and began experimenting along similar lines himself. After some original and daring experiments in this new field opened out by Hertz's work, Marconi conceived of the idea of an apparatus which would detect the presence of these waves. After many trials he developed a crude apparatus which would do this over small distances. He then started in and, by sheer genius and hard work, gave us the child of his brain which he called the wireless telegraph.

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It is a far cry from that day to this, and the near future will doubtless bring just as startling developments as those which the last few years have done.

Since the day when Marconi obtained his patents on the wireless telegraph many of the keenest minds of the scientific world have been constantly at work discovering new facts and perfecting new apparatus.

After the wireless telegraph had become an established fact and more or less perfected, these scientific minds began to cast around for a way to supplant the telegraphy through the ether by the then unknown wireless telephone, just as the line telegraphy had been followed by the line telephone.

Scores of inventors soon had developed methods of transmitting the human voice through the ether without the use of wires, which were more or less successful, and hundreds of others took up the work where their predecessors had left it, until the epoch-making discovery of the vacuum tube wireless detector. This same instrument was soon found to possess wonderful possibilities for transmitting as well as for receiving purposes.

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During the World War this device was so perfected that wireless telephony, or radio-telephony as it is now called, was finally made an established fact as a means of reliable communication. It has since been so perfected that it is used to transmit music with such a truth of reproduction that concerts and opera music are transmitted to listening thousands nightly; and press bulletins, weather reports, stock reports, and all the other items that come under the title of "radiophone broadcasting" are sent out daily.

Thousands of people are equipping their homes and offices with receiving sets, and many thousands more will continue to do so.

Many get the apparatus and struggle with it, trying to master its working, with the meager instructions furnished by the manufacturer. Others have some friend, who knows a little more about radio than they do, erect their sets and show them how to work them. After some time these people finally learn by experience the general theory of radio, enough to keep their sets in working order; but the experience is costly and it takes time to acquire.

This book therefore has been prepared to

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teach the uninitiated the general electrical theory upon which radio is founded and show them how their sets work, how to build them if necessary, how to care for them, and how to make repairs when anything goes wrong. It is written so that all may understand.

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RADIO-TELEPHONY FOR EVERYONE

CHAPTER I

ELECTRICAL THEORY UPON WHICH RADIO IS FOUNDED

IT would be useless to try to explain the subject of the radio-telephone to any one who is not familiar with the simple theory of electricity; but if the reader had a clear though elementary understanding of the electron theory it would be a very simple thing.

Let us start out, then, to get the basic facts of this theory of electricity and matter that explains all phenomena of the scientific world today, both in chemistry and in electrical engineering.

The electron theory is now commonly accepted as fact by the world of science. It deals with the smallest division of matter, which is called the electron.

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The electron is a minute charge of negative electricity; it is the smallest charge that it is possible for the human mind to conceive of.

The atom is the smallest division of matter that exists in the form of matter; it is made up of a nucleus consisting of a positive charge of electricity surrounded by electrons. The only difference between the numerous kinds of atoms lies in the number of electrons which surround the positive charge or nucleus. Thus are explained many chemical changes that occur to substances; the number of electrons surrounding the positive charge of a certain kind of atom may be deprived of a few electrons, and the whole nature of the substance will be changed. These electrons that surround the positive charge are held within certain limits as to the distance they may move from the positive charge by a very powerful though minute force.

To get a clear idea of the atom, we can compare it to the solar system, likening the sun to the positive charge, and the planets to the electrons. The electrons are held in their orbits around the nucleus in much the same manner that the planets revolve around the sun.

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Now let us consider two classes of materials that interest us on account of their electrical property: First, conductors of electricity; second, insulators against electricity.

Conductors of electricity—such as silver, copper, iron, and in fact all metals to a certain extent—will allow electricity to flow through their substance.

Insulators against electricity—such as glass, rubber, wood, air, and numerous other materials—will not allow electricity to flow through their substance.

The conductive materials are made up of millions of atoms, which are in turn made up, as we have just learned, of a positive charge surrounded by minute charges of negative electricity called electrons. But, in addition to these atoms, the conductive materials contain countless numbers of free electrons which float in the spaces between the atoms—somewhat as comets pass through the solar system without collision.

Insulating materials contain very few of these free electrons.

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ATTRACTION AND REPULSION OF FREE CHARGES OF ELECTRICITY

A positive charge and a negative charge brought into proximity to each other will be attracted to each other. Two negative charges will repel each other when brought close together. Two positive charges will repel each other when brought close together. This phenomenon will be more easily remembered if put into the form of a scientific law: like charges repel and unlike charges attract.

If a unit charge of negative electricity is brought near enough to a positive charge the attraction will cause them both to run together and neutralize each other.

THE CURRENT OF ELECTRICITY AND HOW IT IS CREATED

Suppose we take a copper rod (as pictured in Fig. 1-A) which is composed of countless millions of atoms, with millions of free electrons floating in between these atoms, and at one end of the rod we place a strong negative charge or number of charges, All the free electrons in

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the rod, being negative charges, will be repelled from the external negative charge and will scramble about between the atoms in a mad rush to get to the farthest end of the rod from

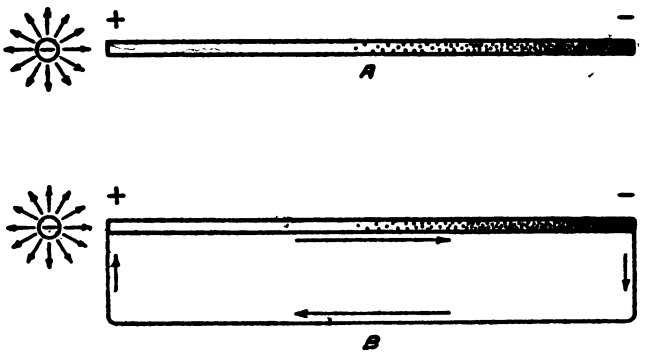

FIG. 1. A shows how free electrons in a copper rod are repelled by placing a negative charge near one end of the rod. B shows how they would flow around through an external circuit, constituting a current of electricity.

the external charge, and will all become crowded together at this end. When a rod or wire is in this condition we say that the end where the negative charges are thickest is the negative end; and the end where there is a scarcity of negative charges is called the positive end. Now if there were a continuous cir-

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cuit around from the negative end of the rod to the positive end, the electrons would rush around through the circuit to the positive end, and we would say that a current of electricity was flowing through the circuit (see Fig. 1-B).

If we were to try the same experiment with a glass rod, we would not have any success, as there are very few free electrons in an insulator and the electric current from these few stray free electrons would be so weak that we could not detect it except with an ultra-sensitive instrument; so we may assume that practically no current of electricity flows through an insulator. If, however, we should apply a very strong external charge, which we might call a high voltage, the free electrons in the glass rod, even though they be very few in number, would be repelled so violently that they would collide with the atoms and knock off some of the electrons that were a basic part of these atoms. These freed electrons would then go racing along with the stream, and soon the matter which composed the insulating rod would be decomposed, and an electric current would flow through the rod in the form of a spark. In this

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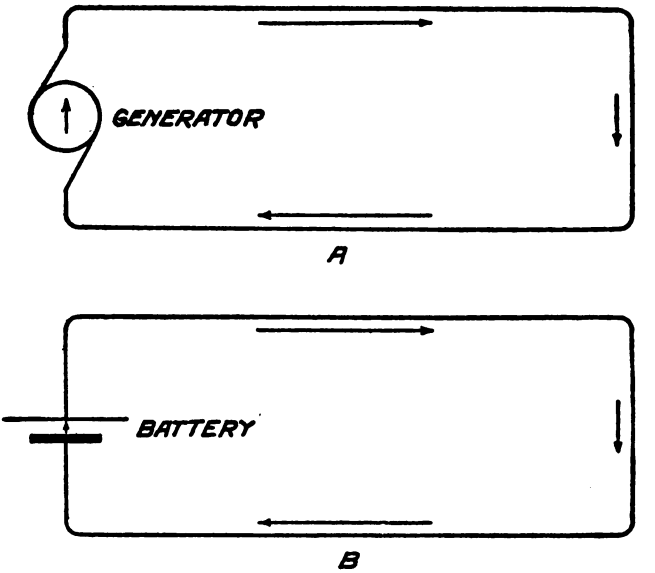

FIG. 2. A and B show how a current of electricity flows through a circuit, when generated by a generating machine or battery. The generator device acts somewhat like a pump.

condition the insulator is called broken down, or punctured.

This same action takes place whenever a spark jumps across an air-gap such as is used in some types of radio transmitting sets. When an atom of air has one or more electrons

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knocked off, its insulating properties are lost and it becomes ionized and is called an ion.

GENERATORS OF ELECTRICITY AND ELECTRIC BATTERIES

An electric generator is a device that causes electrons to be attracted to one of its terminals

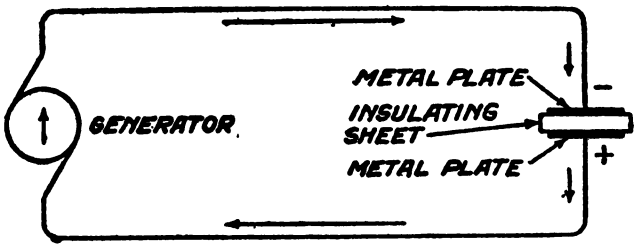

FIG. 3. Diagram showing a generator pumping negative electrons on to one plate of a condenser and drawing them from the other plate.

and repelled from the other terminal, by magnetic action. In other words, if a continuous conducting circuit is connected to the two terminals of a generator (as shown in Fig. 2), the generator will keep on expelling electrons from one terminal and they will flow around through the copper wire to the other terminal, where they will be sucked back in through the

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generator; and then the same process will go on continuously till the generator stops running.

The electric battery does the same thing except that its action is chemical instead of magnetic (see Fig. 2-B).

ELECTROSTATIC ENERGY OR STATIONARY ELECTRICITY

Stationary charges of electricity, or static electricity as it is sometimes called, may be stored up in a device which is known as a condenser. This device consists of two sheets of conducting metal separated by a sheet of insulating material, such as glass, or mica, or in some cases air is used. This sheet of insulator is called the dielectric, and the two conducting sheets are called plates.

Now if we take such a device and connect it to a generator, the generator will suck all of the electrons from one of the plates and this plate will become positive, and these electrons will be pumped by the generator to the other plate, which will then have twice as many electrons as it should have normally. The elec-

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trons cannot get back through the generator, neither can they pass through the dielectric or insulating sheet. If we suddenly disconnect the generator, these electrons which are bunched on the negative plate will remain there, trapped, and we have a store of electrostatic energy in the condenser. When we want to make use of this energy we can connect a wire around from the positive plate to the negative plate and the electrons will rush through the wire, causing a current to flow, till the charge is spent and the electrons are back in their natural places. This action may be likened to the action of water running into a reservoir until the reservoir is filled, where it can be stored until needed, and then the gates may be opened and the water will run out and be used for some useful purpose. The condenser is used for charging up the high voltages used to produce the sparks seen jumping the air-gap in a radio-telegraph transmitter. Condensers are also used for tuning purposes, a use which we will take up in a later chapter.

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ELECTROMAGNETIC ENERGY

When a current of electricity flows through a wire a magnetic field is set up around the wire. This field is the same as the field or magnetic disturbance set up around the poles of a steel magnet as shown in Fig. 4. Imaginary lines

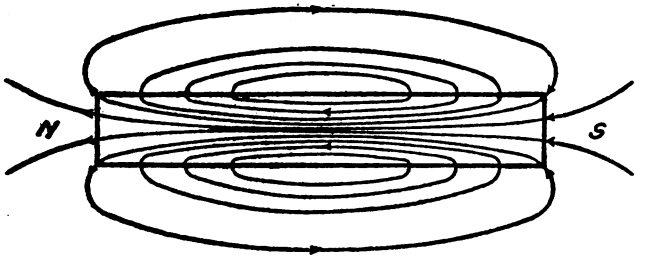

FIG. 4. Magnetic field around a permanent steel magnet. Note how similar to the field set up about a coil as pictured in Fig. 6.

of force—called magnetic flux lines—extend from the north pole of the magnet outside the magnet to the south pole, and inside the magnet from the south pole to the north pole. This magnetic energy is supposed to be revolving around following the paths of the imaginary lines shown in the diagram.

Looking at the end of a wire through which

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a current of electricity is flowing away from us (Fig. 5-A) a magnetic ring starts to revolve around the wire. This imaginary ring expands farther and farther as the current gets stronger, and when the current gets up to its

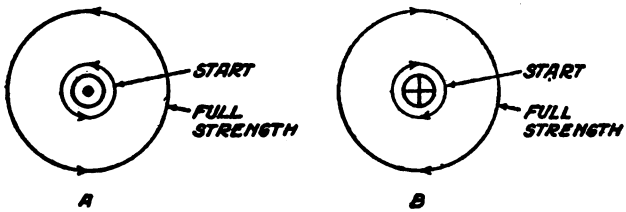

FIG. 5. Magnetic rings around a wire change their direction of rotation when the direction of the current through the wire is reversed. In A the current is flowing away from the reader and in B it is flowing towards the reader.

full strength it stays out at a certain distance from the wire. When the current is turned off, the magnetic ring quickly contracts until it collapses back upon the wire again. If the current should be reversed and flow toward us, the ring would expand in just the same manner and collapse when the current is turned off, but it would revolve in the opposite direction (see Fig. 5-B).

As an analogy we can liken these magnetic rings to rubber bands stretched around the

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wire, fitting the wire tightly. When a current is passed through the wire the bands begin to revolve clockwise, slowly at fist and then more rapidly as the current increases. As the centrifugal force increases from the rotation, the bands expand until, when the current reaches its full strength, the bands have attained their highest speed of rotation and the expansion process ceases and they stand out from the surface of the wire a definite distance, where they remain revolving at a definite rate of speed. When the current is turned off, the speed of rotation decreases and the bands settle back until they come to rest on the surface of the wire. When the current is reversed the bands rotate in the opposite direction and the same process of expansion and contraction are experienced.

When two wires are placed side by side and close together and the current flows in the same direction in both wires, the rings enclose both of the wires (instead of there being two separate sets of rings) and the speed of the rings is doubled. This principle is made use of in the tuning coils of a radio set. Every turn added to the coil increases the magnetic effect, as the wires of the coil are wound close to-

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gether and the current flows in the same direction in the adjacent turns. This causes the magnetic lines of force to encircle the entire coil, extending from one end of the coil outside the coil to the other end, and back through the

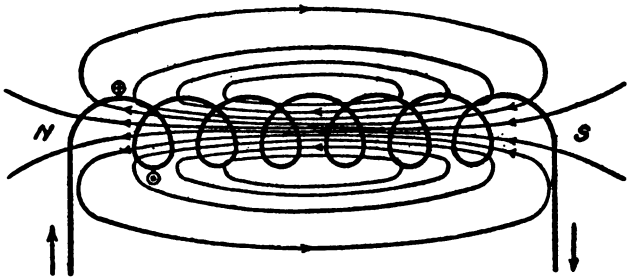

FIG. 6. Magnetic field set up around a coil when a current of electricity is passed through the coil.

inside of the coil. Compare the diagram in Fig. 6 with the diagram of the magnet in Fig. 4.

A coil is sometimes referred to as an electromagnet. One end of the coil will be the south pole, and one will be the north pole, with the current running through the winding in one direction. If the direction of the current should be reversed the polarity of the coil would also be reversed. This idea of electromagnetic energy should be well fixed in the reader's mind

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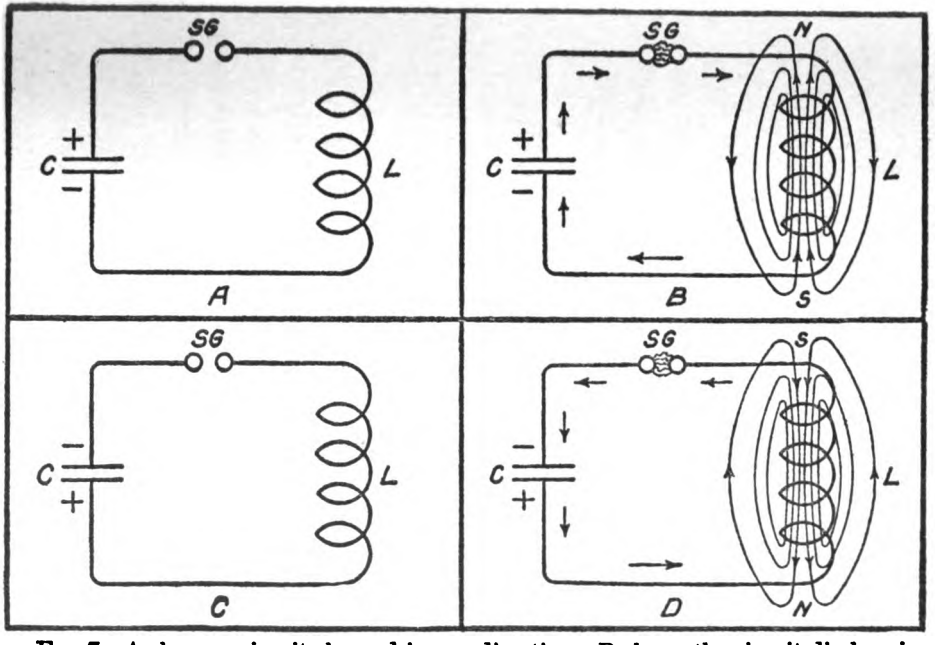

FIG. 7. A shows a circuit charged in one direction. B shows the circuit discharging with a current jumping the gap and continuing around through the circuit. C shows the resultant opposing charge placed on the condenser. D shows the resulant discharge in the opposite direction through the circuit.

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before he proceed further, as it is this principle that is used in all radio apparatus, and it is the "open sesame" to the beginner who wishes to understand more fully the intricacies of radio and the radio-telephone.

These two forms of electric energy—electrostatic and electromagnetic—and the two pieces of apparatus that are used in connection with these two forms of energy—the condenser and the coil, or inductance as it is sometimes called —will now be studied more fully.

If a condenser which has been charged with a high potential or voltage is connected in series with a spark-gap and an inductance coil, as shown in Fig. 7-A, a peculiar action takes place. The positive charge on one plate of the condenser *C* will immediately jump across the spark-gap *S* and pass through the coil *L* in an effort to get around to and neutralize the negative charge on the other plate of the condenser *C*. In doing so a current of electricity is caused to flow around through the circuit.

Now, as we have just learned, when a current of electricity flows through an inductance coil a magnetic field is set up in the space around the coil. This field is shown in the dia-

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gram (Fig. 7-B); one end of the coil is made north in polarity, and the other end south. The field increases in intensity as the current increases, in its rush through the circuit.

When the charges in the condenser have neutralized each other, of course the current stops flowing and the magnetic rings around the coil begin to contract. Now we observe another effect produced by these magnetic rings settling back upon the windings of the coil. As the imaginary rings contract, or settle down, a current is induced in the winding of the coil, which flows in the same direction as the current just ceasing. This current places a positive charge on the plate of the condenser *C* which was at first negative, and causes the other plate to be charged negatively. This action is called electromagnetic induction, and all radio instruments for transmitting and receiving make use of this action.

Now we have the charges on the condenser *C* just reversed. The charges, however, are not quite as strong as the first charge, due to the resistance offered to the electric current through the circuit and the loss of energy spent in producing light, heat, and sound in the spark-

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gap *S*. This last charge in the condenser is shown in Fig. 7-C.

The same action is then gone through again. The positive charge starts to flow around through the circuit in the opposite direction, causing the magnetic rings to revolve in the opposite direction, thus changing the polarity of the coil *L* and causing another spark to jump the gap *S*, as shown in Fig. 7-D.

This series of current impulses going through the circuit, first in one direction and then in the other, continues, each succeeding impulse becoming weaker than the preceding one however, until the voltage on the condenser becomes too low to jump the spark-gap *S*. Then the oscillations, as they are called, cease.

A diagram of the succeeding reversals of these currents and the weakening of these impulses is shown in Fig. 8. One whole set of these impulses takes place for one charge placed in the condenser; and the whole set takes place in the twinkling of an eye, so to speak, and the whole series of sparks across the gap may look like a single flash, they follow each other with such rapidity.

It takes two impulses to make a cycle—one in

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one direction, and another in the reverse direction, as shown. These oscillations used in radio have a frequency of 10,000 to 3,000,000 cycles per second. The number of cycles per second to be generated in such a circuit as described

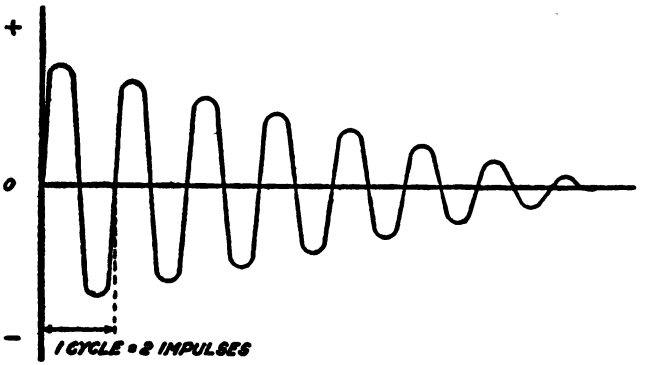

FIG. 8. This diagram illustrates the current generated by a condenser discharge through a spark gap and tuned circuit. The two opposing impulses shown above, called a cycle, are the result of the discharges diagramatically shown at A B C D in Fig. 7.

above is governed by the size of the condenser *C*, and by the number of turns of wire on the coil *L*. It can easily be seen that if *C* is a small condenser, it can be quickly charged and discharged, and if *L* is a few turns of wire a current can pass through it rapidly. This will give

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us a quick succession of reversing impulses, and a high frequency, such as 3,000,000 cycles per second. Now if we use a larger condenser it will take a longer time to charge and discharge it, and if we increase the number of turns of wire on *L*, a current will take a longer time to pass through it. This gives us a slower succession of reversing impulses, or, in other words, a lower frequency. In this way we can pick out the wavelength we wish to send out signals on, by changing the values of inductance or capacity in the generating or oscillating circuit. This is because each frequency corresponds to a definite wavelength. We will go into this subject of radio waves and wavelength more fully in the next chapter.

The electric action that takes place in an oscillating circuit may be compared to the mechanical action of a pendulum. If we give a pendulum a push, it moves first in one direction a certain distance (one impulse), falls back to its original position, and then moves in the opposite direction (the reverse impulse), and then comes back to its original position again; and the same cycle is repeated over and over. At each impulse, or time the pendulum swings, it

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does not swing quite as high as the preceding time, until finally it comes to rest and the oscillations stop. We can change the frequency of these impulses by lengthening the pendulum or increasing the weight at the end of it.

The same general scheme of action takes place in the electrical oscillating circuit, except that the oscillations are electrical instead of mechanical. These oscillations are called damped oscillations because they finally are damped out or decreased by the action of resistance and finally die out. Undamped oscillations and methods for generating them will be studied in a later chapter.

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CHAPTER II

GENERAL THEORY OF RADIO WAVES

A RADIO-WAVE is a vibration through space.

There are many different kinds of vibrations that travel through space: that is to say, certain vibrations produce entirely different results from other vibrations.

Suppose we consider, for example, a flexible reed, fastened to a stationary base, as shown in Fig. 9. If we cause the reed to vibrate, it will first take the position *A*, and then swing back and past its original position to a third position *B*, and then back to its original position again, in much the same way that a pendulum swings. Then the same series of movements will be gone through again. This set of movements is called a cycle, as we have already learned.

Now if we have the reed vibrate at a speed of 16 cycles per second, the reed will cause a sound to be propagated in the immediate space surrounding it. This wave will make itself

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manifest to our sense of hearing in the form of a low humming sound. Near the reed it will be fairly loud but at a distance of fifty feet it may be inaudible.

If we increase the frequency, or speed of vibration, to 500 cycles per second, the low hum

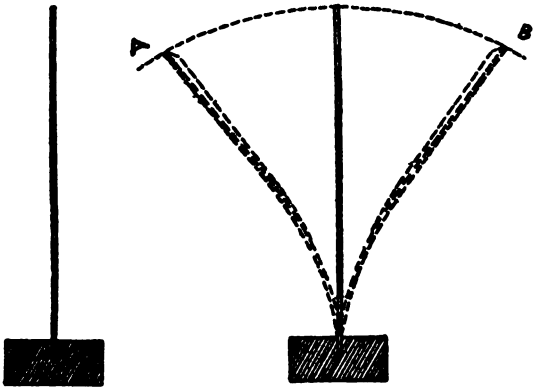

FIG. 9. One method of producing sound waves is to cause a slender reed to vibrate back and forth.

will increase in pitch until it will be a shrill whistle like the high notes of an organ.

If we continuously increase the frequency of the oscillations, when we reach 2,500 cycles per second the sound will have gotten so high that the human ear cannot hear it. In other words, the waves that are generated around the reed

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have gone out of the range of frequency that we call sound-waves.

As the frequency is increased it will soon be noticed that the reed begins to get warm, until finally, by placing the hand near it we feel the heat-wave. This heat-wave is of exactly the same nature as the sound-wave, except that it has a different frequency and produces different results. In one case we hear the sound with a recording organ called the ear, and in the other case we feel the presence of heat by our sense of touch.

As the frequency of the little reed is increased beyond this point, the heat developed finally increases until the reed begins to glow a dull red color. Instantly the wave has become a light-wave and is visible to our eyes, but the heat is still felt. This shows that the ranges of heat and light overlap in the frequency scale.

Any further increase of frequency would mean destruction to the reed through overheating; but if we could imagine its frequency as increasing without burning up, the waves sent out would pass through the ranges of color, and the X-rays.

To sum up: Different ranges of frequency,

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say 16 to 2,500 cycles, produce waves that we call sound; and another range produces heat, light, and color. Another range produces X-rays; and a similar range produces waves that we call Hertzian waves, named after Hertz, the man who discovered their existence. And these Hertzian waves are our radio waves. The frequency that produces them, as we have already stated, lies within the range of 10,000 to 3,000,000 cycles per second.

We know now what a sound-wave is. Did we ever notice that the seats in a theater are invariably arranged in a semi-circle? This is done to take advantage of the fact that all waves—such as sound-waves, light, heat, and also radio-waves—travel in ever-increasing circles.

You will get some idea of how radio-waves travel by observing what happens when a stone is thrown into a pool of still water. A circular wave is at once formed around the spot where the stone hit. This circular ripple begins to travel outward, with its diameter ever getting larger, until it dies out. If we place a cork on the surface of the water, near the spot where the stone has struck, it will bob up and down

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violently as the wave passes by. If the cork were to be placed on the water at a distance from the same spot, the vertical movement would be much less violent because the wave would be weaker after traveling this distance.

Or take another illustration: We know that a fire built in the woods is hot on all sides and will warm people standing on one side of it just as much as it will warm those on the other side. If we move closer to the fire, the heat increases because the heat-waves are stronger there; if we move away, the heat decreases. This also is because the waves weaken as they travel.

The same general conditions hold true for radio-waves. The transmitting station may be likened to the stone thrown into the water, and the receiving station to the corks on the surface of the water.

How the radio-waves are sent out is shown in the diagram in Fig. 10. The antenna is shown, for simplicity, as a single wire vertical antenna with a spark-gap as a generator of oscillations, in series with the ground. For every given frequency of current jumping the gap, a wave of a certain definite length is radiated from the antenna. The length of the wave

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is the distance between the start and finish of one complete wave, measured along the ground. All radio-waves travel with the terrific speed of light, 300,000,000 meters per second. When we know this, the wavelength of a

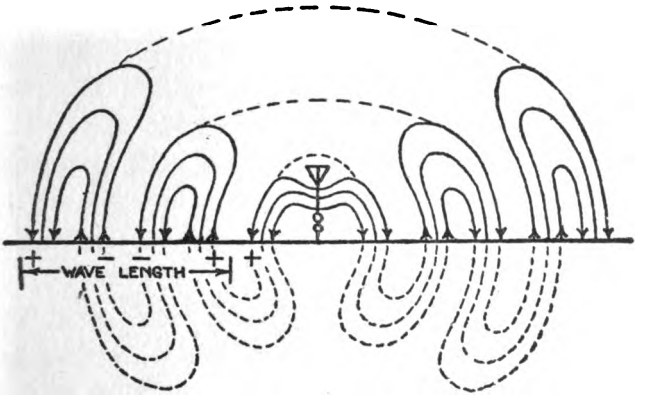

FIG. 10. How radio waves leave an antenna and spread in widening circles.

wave radiated from an antenna can be easily calculated, provided we also know the frequency of the electric oscillations in the antenna circuit.

A table of wavelengths used for radio communication is given here as a matter of interest, showing the frequency of the electric currents which cause them to be emitted from an antenna.

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Wave length in meters	*Frequency in cycles per second*	*Type of station which uses each wave length*
200	1,500,000	Amateur stations
300	1,000,000	Ship stations
360	834,000	Radio-telephone broadcasting stations
450	667,000	Ship stations
600	500,000	Commercial ship and shore stations
1,000	300,000	U. S. Navy
1,400	214,300	Commercial traffic
2,600	115,400	Time signals
5,000	60,000	High powered commercial stations
10,000	30,000	" " " "
15,000	20,000	" " " "
20,000	15,000	" " " "
30,000	10,000	" " " "

It will be noticed from the above table that as the frequency of the current in the antenna decreases, the length of the emitted wave increases.

Now let us consider how radio-waves are received.

We "receive" a radio-wave when we erect an antenna with its insulated wires high in the air, and these wires get in the way of the advancing circular-shaped radio-waves. When a series of waves strike the antenna they do not cause it to bob up and down, of course, but

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they do produce a tangible result nevertheless. This result takes the form of a feeble current in the receiving antenna which is an exact replica of the current in the transmitting antenna, but reproduced on a much smaller scale. It has the same frequency as the transmitter current and is like it in every respect, except in strength.

Thus we can readily see that it is not the electric current itself that travels through space, but that the electric current does start a disturbance in the space around the antenna in the form of a Hertzian wave which travels outward in all directions in circles. And when these waves strike another antenna which is tuned to that particular wavelength, they will induce in that antenna a current similar to the transmitter current, only of decreased intensity.

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CHAPTER III

THE VACUUM TUBE, FOR GENERATING OSCILLATIONS

IN a preceding chapter we learned how the oscillating circuit worked and how a condenser by discharging through a spark gap and an inductance in series, which constitutes an oscillating circuit, produces oscillations that gradually get weaker and weaker until they die out. And we also learned that these oscillations that gradually die out are called damped oscillations on this account. These produce radio waves in space that upon being received by a radio receiver produce sounds in the receiver that we all would recognize as the regular radio telegraphy; buzzing sounds that would drown out the voice if this method of producing radio waves were to be used for radio telephony. Hence, to do away with this objectionable feature of the spark method of generating radio waves, has been one of the problems that the greatest radio engineers and inventors have been trying to solve since radio telephony was

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first conceived. The general consensus of opinion throughout the radio field of science was that the correct angle of approach to the solution of this problem was to develop a generator of oscillations that would produce oscillations whose frequency would be above the frequency that the human ear could hear. In other words, what was wanted to make a success of the radio telephone was a wave that would be inaudible, until the frequency of the human voice was impressed on it.

The solution to this problem has been found in the vacuum tube. The vacuum tube can be used for a generator of oscillations, the frequency of which can be controlled at will. It can be used to produce oscillations that will not have any effect upon a receiving set, that is, will not be heard in an ordinary receiver, but will carry a voice wave that is impressed on them, so that the voice wave *will* produce sounds in the receiver.

We will now take up the study of the vacuum tube which is now used extensively for numerous purposes wherein radio is involved.

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THE VACUUM TUBE

When an atom becomes heated, the electrons of which it is composed begin to move more rapidly in their orbits around the central attracting nucleus and if heated beyond a certain point the movements of the electrons become erratic and some of the electrons break away from the attraction of the nucleus and shoot away from the atom. This eventually results in the decomposition of the atom.

Edison, while pursuing his researches on the electric lamp, discovered this effect. He found that when a filament of an electric lamp was heated that the space around the heated filament became charged with negative electricity. This is nothing different than stating that the atoms of which the filament is composed, upon heating, begin to decompose and give off electrons which shoot like comets away from the surface of the filament. Upon putting a small metal electrode into one of his lamps, Edison found that when the lamp was lit, he could pass a current of electricity across from the plate to the filament. The current of electricity is always considered as flowing in an opposite

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direction to the electrons. This meant that when the filament was hot the electrons would

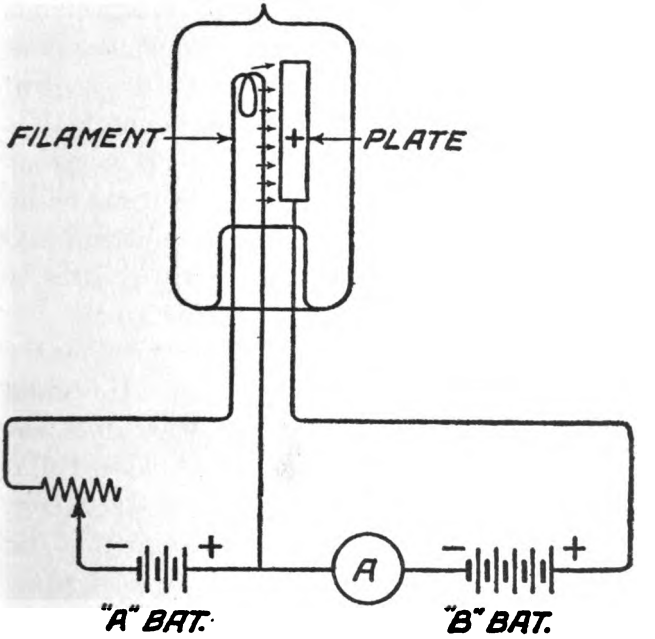

FIG. 11. The Fleming valve rectifier. When a current of electricity is caused to flow through the filament, electrons leave the filament and are attracted to the plate on account of the positive charge on the plate. This electron flow can be measured by the ammeter A.

pass across from the filament to the plate. This action of the filament emission of electrons

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was accordingly named the "Edison Effect." Fleming later made use of this action in his Fleming valve, which he used for a rectifier of alternating currents on account of the tube passing current in one direction only. Fig. 11 shows such a tube connected up with a "B" battery, the positive terminal of which is shown attached to the cold electrode called the "Plate." The positive charge that is thus supplied to the plate tends to draw the electrons, which are negative, over from the filament with much greater attraction and force, because of the attraction of unlike charges which we studied in the first chapter. The path of the electrons from the filament to the plate is indicated by arrows. The current flowing across the gap can be measured by the ammeter.

Deforest still later found out that he could control the amount of current flowing over the gap from the plate to the filament by inserting a third electrode in the tube, which he called the grid, so called because it resembled a grid iron, being made of a wire mesh.

By placing a positive charge on the grid, it was found that the three element tube acted

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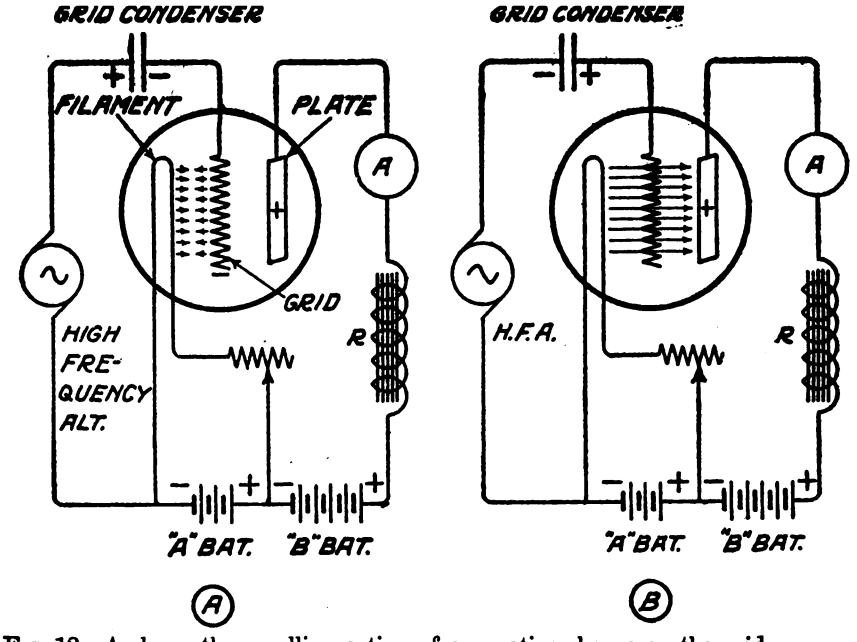

FIG. 12. A shows the repelling action of a negative charge on the grid; no current flowing from the plate to filament. B shows the attracting action of a positive charge on the grid; a large current flowing from the plate to filament.

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in the same manner as the two element tube. That is, a current of electricity would pass from the plate to the filament. When a negative charge was placed on the grid, the current flowing through the plate to the filament was interrupted and ceased to flow. In Fig. 12A

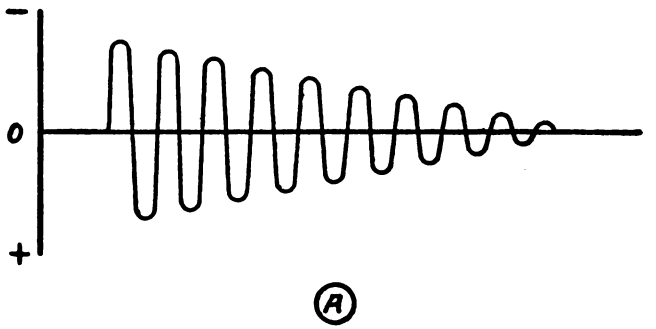

FIG. 13A. High frequency voltages applied to a grid of a vacuum tube.

such a three element tube is shown with a negative charge on the grid. It will be seen from the small arrows representing the electrons emitted from the filament and the small arrows indicating the negative charge on the grid that there is a repelling effect of this negative charge on the grid. In Fig. 12B, the grid is shown charged positively and the electrons are

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more strongly attracted from the filament, and a greater current is allowed to flow from the plate to the filament. The circuit which includes the grid and the filament is called the input circuit and the other circuit which includes the plate and the filament is called the

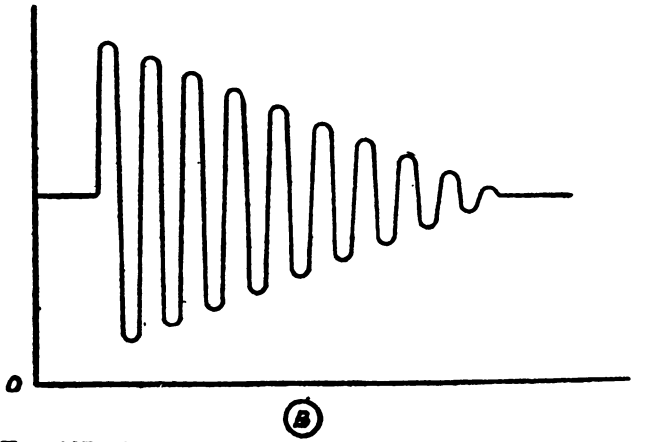

FIG. 13B. Plate current resulting from grid voltage shown in Fig. 13A.

output circuit. If a high-frequency current as shown at Fig. 13A is supplied to the input circuit by a high frequency alternator, the grid will be alternately charged positive and negative. While the grid remains uncharged exter-

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nally, a certain amount of direct current will be flowing in the output circuit and when the oscillating voltage is applied to the input circuit, the current in the output circuit is varied

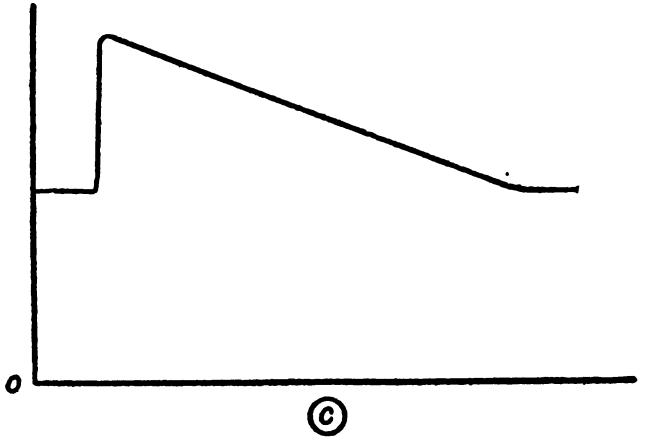

FIG. 13C. Telephone current resulting from oscillations applied to grid of vacuum tube as in Fig. 13A.

by the same wave form as the voltages applied to the grid. This results in a direct current of varying strength which has the same wave form as the input voltage and this current is shown in Fig. 13B. If an energy absorbing device, such as a pair of telephones is connected in series with the output circuit, the

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rapidly changing current values of this circuit will be smoothed out and the whole series of impulses changed into one large impulse, such as shown in Fig. 13C. It will be noticed that the outside shape of this impulse is the same as the outside shape of the combined series of smaller impulses.

This valve action of the audion or electron relay, as the vacuum tube is sometimes called, is made use of for both transmission and reception of signals.

If this same electric tube is connected up to a circuit similar to the oscillating circuit we have studied in the preceding chapter, the tube will generate electrical oscillations, the frequency of which is controlled by varying the amount of inductance or capacity in the circuit. Thus the audion becomes a generator of continuous waves which can be sustained at a frequency that is inaudible to the human ear and if the voice waves are superimposed on this high frequency current they will be carried out into space in the form of Hertzian waves.

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THE VACUUM TUBE AS A GENERATOR OF OSCILLATIONS

An oscillating circuit is shown in Fig. 14. The vacuum tube, as before stated, when connected up with an external oscillating circuit will cause a high frequency electrical alternating current to flow in the external circuit. The circuit functions in the same manner as the oscillating circuit which relies on the charge and discharge of a condenser through a spark gap. The only difference in operation of a vacuum tube oscillating circuit is that the vacuum tube supplies the loss in the circuit due to the resistance of the circuit to the current flowing through it. It will be remembered that each successive impulse as generated by the spark discharge method is of a lesser value than the preceding impulse. In the vacuum tube oscillating circuit, however, the amount of current spent in each impulse due to resistance is supplied to the circuit through the vacuum tube. In this way the successive oscillations flowing in the vacuum tube oscillating circuit are of constant value and flow continuously

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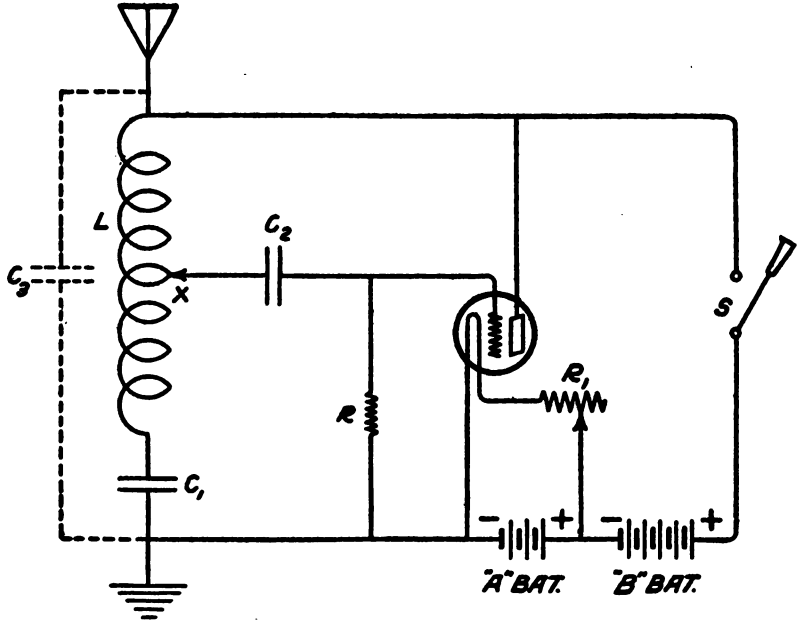

FIG. 14. A vacuum tube connected to an oscillating circuit for producing radio frequency currents.

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without dying down. Hence their name, continuous waves.

Fig. 15 is a diagram of such a continuous wave and the reader can compare this with the

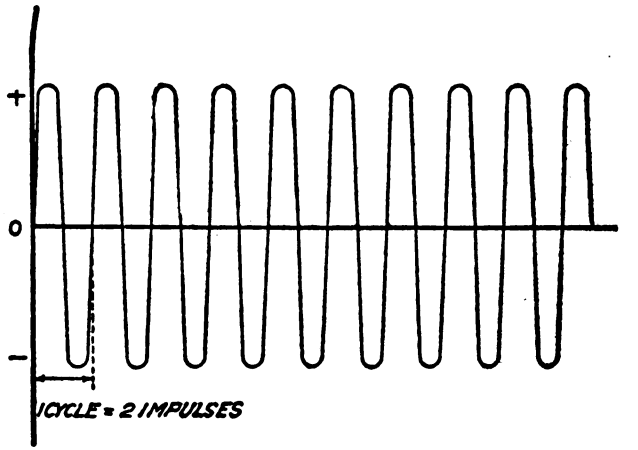

FIG. 15. High frequency oscillations as generated by a vacuum tube oscillator. These oscillations form a continuous wave of uniform amplitude.

diagram in Fig. 8, which shows waves of decreasing strength as generated by the spark discharge method.

On account of the continuity of the wave generated by the vacuum tube, there is only one frequency present and this is of so high an order that it is inaudible to the human ear.

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Referring again to the oscillating circuit shown in Fig. 14; when the Switch "S" is closed, a direct current flows from the "B" battery and charges the condenser "C 1." A current also flows across the vacuum tube from the plate to the filament. The first current causes a magnetic field to be set up in the vicinity of the coil "L," and when condenser "C 1" becomes fully charged, the magnetic field around the coil "L" collapses and places a negative charge on the grid of the vacuum tube which stops the flow of current through the vacuum tube and causes condenser "C 1" to discharge through the imaginary condenser "C 3." This condenser "C 3" is the electrical capacity between the antenna and the ground. A current is then built up in the coil "L," which produces another magnetic field in the vicinity of the coil with the opposite polarity, and charges condenser "C 1" momentarily in the opposite direction. At this instant the grid of the tube is charged positively and current is allowed to flow from the plate to the filament. The correct potential to be supplied to the grid to maintain oscillations is obtained by the vari-

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able contact "X" by which the inductance is varied until the correct potential is found.

The condenser "C 2" is used to insulate the grid from the direct current from the "B" battery. The grid leak resistance "R" is used to prevent the grid from becoming too negative in potential and thus preventing the tube from becoming inoperative. The resistance "R 1" is inserted in series with the "A" battery to control the current flowing through the filament of the tube and thus keeping the filament at the correct temperature.

The frequency of the oscillations generated by the vacuum tube method can be used to produce radio waves of wavelengths suitable for radio telephony both for commercial and for amateur use. These wavelengths lie between 150 meters and 30,000 meters. The radio frequency currents of such a continuous wave as shown in Figure 15 are between frequencies of 10,000 cycles per second and 3,000,000 cycles per second. These frequencies are above the frequencies which can be detected by the human ear, and, therefore, are suitable for use in radio telephony for the reason before stated. That

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is, in a receiver, no sound will be produced until the operator speaks into the transmitter although the current is flowing all the while.

The vacuum tubes used for this purpose are of much larger size than the ordinary vacuum tube used as a detector of radio signals. The smallest tube used for generating oscillations for transmission will generate electrical current at about five watts energy. The largest tubes used, such as in a large broadcasting station, have an output of between 250 and 500 watts and tubes are being developed capable of handling much greater powers. The watt is a unit of electrical energy. These high power tubes have a very high vacuum and the elements in the tubes (the filament, plate and grid) are made of materials which can withstand a great amount of heat. There are numerous self-cooling methods being developed for getting even larger powers out of the vacuum tubes when used as generators.

It should be understood that the vacuum tube in itself will not generate oscillations, but when connected to an oscillating circuit it will cause oscillations to be built up in this circuit and will supply currents at just the right instants

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which are used up in the circuit in replacing energy lost, due to the resistance of the circuit. The supply current made use of by the vacuum tube for this purpose is a direct current which is supplied at the correct intervals just when needed to sustain the oscillations flowing in the circuit.

The action of the vacuum tube oscillator, in other words, is very much like the case of a pendulum which is swinging back and forth and kept swinging the same distance in each direction by someone giving it a little push each time the pendulum swings toward them. We all know that with a child in a swing, the child and the swing can be kept oscillating back and forth with a slight push applied at just the correct instant, and this is what the vacuum tube does when connected to an oscillating circuit. It gives the circuit the electric push at the end of each cycle, which sustains the oscillations in the circuit and does not allow them to die out.

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CHAPTER IV

MODULATION—MOLDING THE HUMAN VOICE INTO THE OSCILLATIONS

WHAT is Modulation?

Modulation is the molding of the continuous radio wave such as generated by the oscillating audion into the form of the human voice, music or any other sound that may be desired to be transmitted. There are a number of methods for obtaining this result. One of the simplest methods is to insert a telephone transmitter or microphone in series with the antenna circuit, through which the high frequency oscillating currents are flowing. When the voice waves hit against the diaphragm in the transmitter, the resistance of the transmitter is varied in accordance with the voice wave and this resistance being in series with the antenna circuit, the current flowing in the antenna circuit is varied in strength in accordance with the voice-waves. A voice wave is

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shown in 16. A continuous wave modulated by voice waves is shown at 17. It will be seen how the outline of the continuous wave follows the outline of the voice wave. The transmitter in the antenna circuit is one of the simplest methods of modulation, but it has the serious limita-

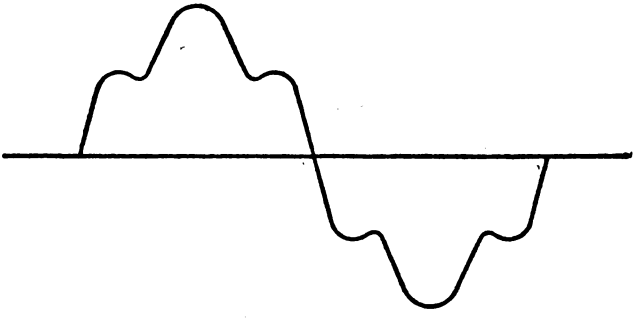

FIG. 16. Graph of a voice wave.

tion of not being able to modulate large currents on account of the currents heating up the transmitter and thus making the carbon grains in the transmitter coagulate.

Another method of "modulating" a continuous high frequency current is called "Absorbtion." This consists in using a single turn of wire around the antenna inductance shunted by the transmitter or microphone. In this system

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the antenna inductance induces a low voltage in the single turn of wire, and the microphone being in series with the loop absorbs a varying amount of current as the voice waves are impressed on the diaphragm of the transmitter. This system will handle larger currents than the first mentioned system, but it has the same general power limitations (see Fig. 18).

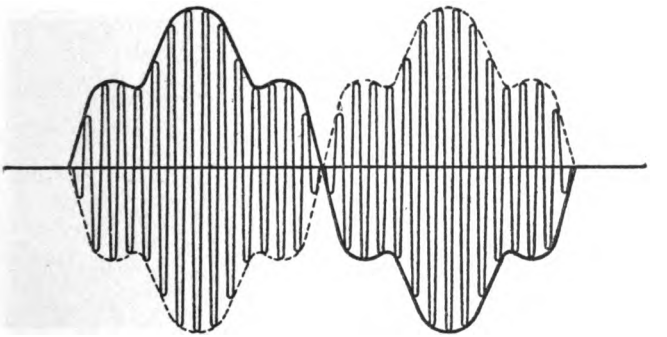

FIG. 17. Oscillograph of a continuous wave modulated by the voice wave.

The third method of modulation which we will consider, is called "grid modulation." We have learned that a vacuum tube will pass larger currents when a negative potential is applied to it, and very small currents when it is charged to a positive potential. This system

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takes advantage of this phenomenon and is shown in the diagram Fig. 19. As shown in the diagram, the grid circuit has included

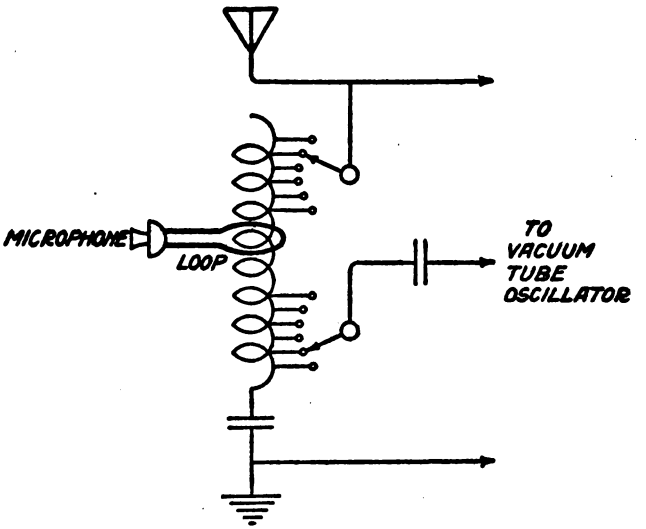

FIG. 18. The absorption method of modulating the high frequency currents in a radio telephone transmitter by placing a single turn of insulated wire around the inductance and connecting to a microphone.

in it the secondary of a step-up transformer whose primary coil is connected to a battery and a microphone transmitter. When the human voice is impressed on the microphone

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transmitter a pulsating direct current is caused to flow through the primary of the transformer and the voltage is transformed to a higher voltage in the secondary winding of the trans-

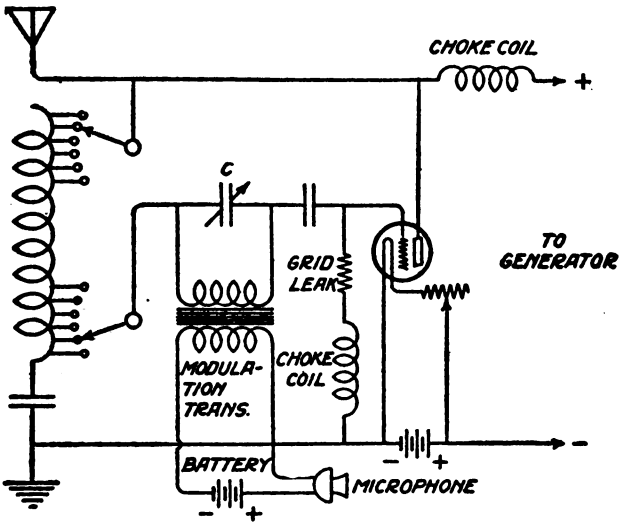

FIG. 19. The grid method of modulation, using a modulation transformer to step-up the voltage of the voice currents and thus modulating the high frequency currents by applying these voltages to the grid of the vacuum tube.

former, and this voltage is thus used to charge the grid condenser to the varying voice potentials. As stated before the charge of the grid

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controls the amount of current that is allowed to pass through the vacuum tube, and when the voice wave is high the grid voltage is high and the current passing through the tube is high. When the voice wave is low, the grid voltage approaches zero and the tube current decreases. The amount of high frequency current that is being generated by the circuit is thus controlled and the high frequency current is molded into the shape of the wave of the voice spoken into the microphone. This type of modulation gives quite good speech, but it is quite critical in adjustment, and the adjustment must be changed when the wave-length that the station is transmitting on is changed. The adjusting for a good quality of speech is accomplished by varying the grid tap shown on the diagram. Sometimes a condenser C is connected across the secondary winding of the transformer and the quality of the speech adjusted by variation of the condenser. The transformer used for this purpose is called a modulation transformer, and it consists of a primary low voltage winding and a secondary high voltage winding, both wound on a soft iron core. The battery used in the primary is usually a

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six volt battery. This type of modulation will handle larger currents than the two preceding methods described, although the overall efficiency is rather low. Another type of modula-

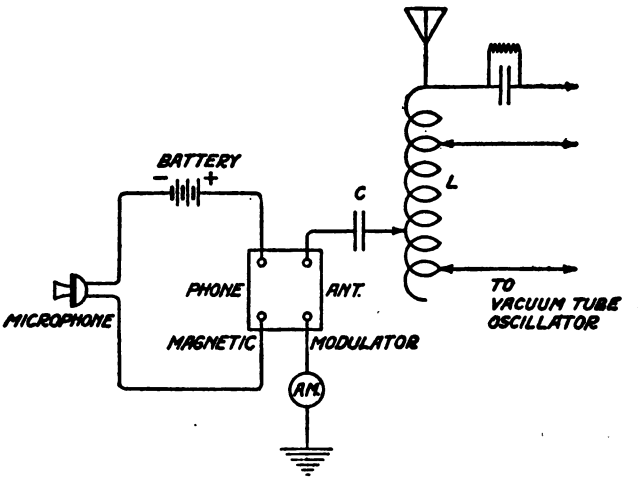

FIG. 20. Magnetic modulation is accomplished by connecting a special transformer in the antenna circuit, which acts like a varying resistance in this circuit. The variations being controlled by the voice waves spoken into the microphone.

tion that is known as magnetic modulation has been developed and is very simple in operation and will modulate fairly large currents and is entirely non-critical in operation (see Fig. 20).

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It consists of a transformer that has a low resistance winding and a secondary absorbing winding that is connected to a microphone. The resistance of the primary winding which is placed in series with the antenna, is varied in accordance with the voice waves that are impressed on the diaphragm of the microphone transmitter. The general scheme is much like that in the case of the transmitter in the antenna circuit, but it has the great advantage of being able to handle much greater currents without heating up the transmitter.

The best system of modulation is known as constant current modulation as developed by Heising. This system is diagrammatically shown in Fig. 21. Two sets of vacuum tubes are used, one set called "Oscillators" and the other set called "Modulators." A "constant current coil," marked C in the diagram, is inserted in the lead wire to the plates of the tubes. The function of this coil is to keep the combined current flowing to the two sets of tubes constant, and the success of the whole system hinges on this point. The modulator tubes are connected by their grids to the modulation transformer secondary winding. This

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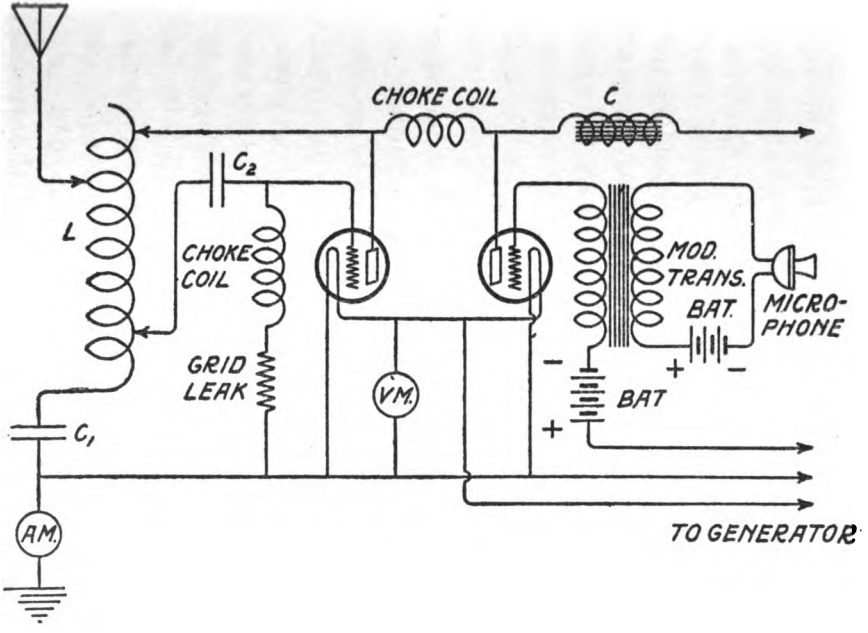

FIG. 21. Heising modulation. Two sets of tubes are used. The tube on the left is the oscillator and the tube on the right is the modulator.

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transformer is just the same as the transformer used in the grid modulation scheme. The voice is transformed into an electric current by the microphone transmitter and battery and the voice current oscillations stepped up to a higher voltage by the modulation transformer and these voltages are then used to control the modulator tubes and make them draw large or small amounts of current through the constant current coil. The oscillator tubes go on generating high frequency current all the while and as the constant current coil will always pass the same current all the while and the modulator tubes draw varying amounts according to the voice waves which are impressed on the diaphragm, so the oscillator tubes while oscillating generate feeble currents or strong currents as the voice waves change in strength. In this way the continuous wave high frequency currents are modulated up and down into the shape of the voice waves. The Heising scheme is the best one of all the various methods as it works independent of wavelength and will handle any amount of power and the speech produced is perfect. The same number of tubes are used as modulators as are used as

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oscillators, one oscillator and one modulator, or two oscillators and two modulators and the tubes must be of the same power. More modulated energy is put into an antenna with two tubes, one used as an oscillator, and one used as a modulator than with two tubes used as oscillators with grid modulation, and the quality of speech is not to be compared with any other scheme as it is by far the best. We will go more deeply into the details of the constant current method of modulation in a later chapter when the structural details and operation of such a transmitting set will be studied.

A transmitting microphone is a device that is used to convert sound waves into electrical currents. It consists of a thin metal diaphragm, which is fastened in the center to a movable part of a cup shaped container. The other half is stationary. This container is filled with minute grains of carbon. Carbon is a conductor of electricity. One-half of the cup is connected to one wire of a circuit and the other half of the cup is fastened to the other wire of the same circuit. When the voice waves are impressed on the diaphragm, the one-half of the cup moves with the diaphragm

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back and forth, thus compressing the carbon grains and releasing them alternately. If the microphone is connected in series with a bat-

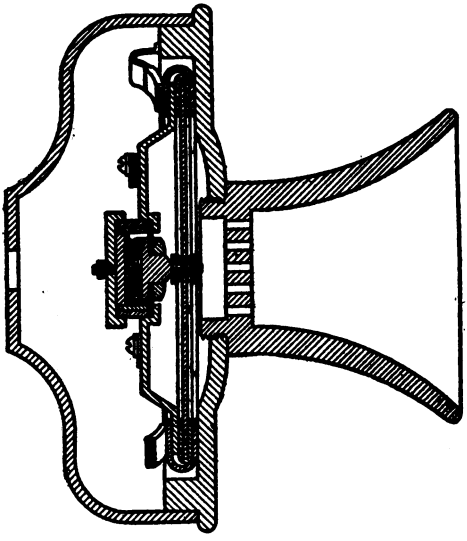

FIG. 22. The diaphragm is fastened to one side of the cup, which moves back and forth with the diaphragm. The other half is stationary. The space within the cup is nearly completely filled with carbon grains.

tery, the resistance of the carbon will vary with the vibrations of the voice as the carbon grains are pressed together and make a good connection and fly apart thus making a poorer connec-

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tion. This causes the current from the battery to flow through the microphone in impulses which correspond to the voice waves which hit the diaphragm and thus the voice is changed into an electric current. See Fig. 22 for a sketch of the microphone transmitter.

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CHAPTER V

THE AERIAL OR ANTENNA, STRUCTURAL DATA

AN antenna which has a current of a very high frequency flowing in it will cause a radio wave to be set up in the surrounding space which will spread in ever increasing circles, expanding and weakening as they travel great distances, with the speed of light. The high frequency current may have been produced by the vacuum tube oscillator which we took up in a preceding chapter. This high frequency current may have been modulated or molded into the wave form of the human voice or music or any other sound by a process which has also been studied and which is termed "Modulation."

There are some facts regarding the functioning of the antenna as a general subject that we might give some time to study as well as the different types of antenna systems and the electrical characteristics of each of these systems.

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THE AERIAL OR ANTENNA

The antenna in general is used to start a wave motion through space, and the wave motion consists of two components, a capacity component, and a magnetic component. In other words there are two sorts of fields set up around an antenna, one an advancing electro-static field, and the other an advancing electro-magnetic field. These in combination produce the wave motion that we know as the Hertzian wave.

Now as there are two components to the wave we should expect that different types of antenna should rely for their action on one or the other component or possibly a combination of both. This is the case. Antennae are divided into two general classes: 1. The capacity antenna or the over head or underground antenna, and 2. The magnetic antenna or the different forms of loop antennae.

The capacity antenna is a number of elevated wires stretched approximately horizontal to the ground, with a suitable "lead-in" wire or wires which run down to the radio instruments. With this type of antenna a ground connection is necessary and this ground may consist of a wire running from the instruments connecting with some metallic underground system such as

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a water pipe, or a gas pipe, or a metal plate or wires of sufficient size buried in the earth.

The capacity antenna may be considered as a large condenser, having for one plate the overhead wires, and for the other plate the ground itself (which is a good conductor of electricity). The successive high frequency

FIG. 23. The insulator is used to prevent the electrical energy leaking off the antenna to the ground through the antenna supports.

impulses charge this huge condenser which uses the air as its dielectric, or insulating plate, and thus start the wave-motion through space. Of course, it will be seen that if the antenna is to be efficient, the elevated wires will have to be well insulated to prevent the leakage of electricity from the antenna to the ground. This is accomplished by numerous forms of insulators, one of which is shown in Fig. 23. These insulators are made of a section of insulating material, tubular shaped and with a corrugated surface to make the leakage path as

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long as possible. They are generally provided with two metal loops or some form of hole, one in each end, to attach the wires to.

The capacity form of antenna may be subdivided into the following classes:

1. Inverted "L" type.
2. "T" type.
3. Umbrella type.
4. Vertical type.
5. Fan type.
6. Cage type.

1. The inverted "L" antenna is probably the most popular type of antenna because of the ease with which it is erected and also because of its high efficiency for both transmission and reception. It consists of one wire, or a number of horizontal wires connected in parallel with a lead-in wire or wires attached at one end. It gets its name because of the similarity of its shape to the letter L turned upside down (see Fig. 24). A piece of wire or rope is first connected to a high pole or any other elevated structure, with an insulator connected to it. The antenna wire is then fastened to the other end of the insulator and a length of about 100 feet of this wire is let out and fastened to

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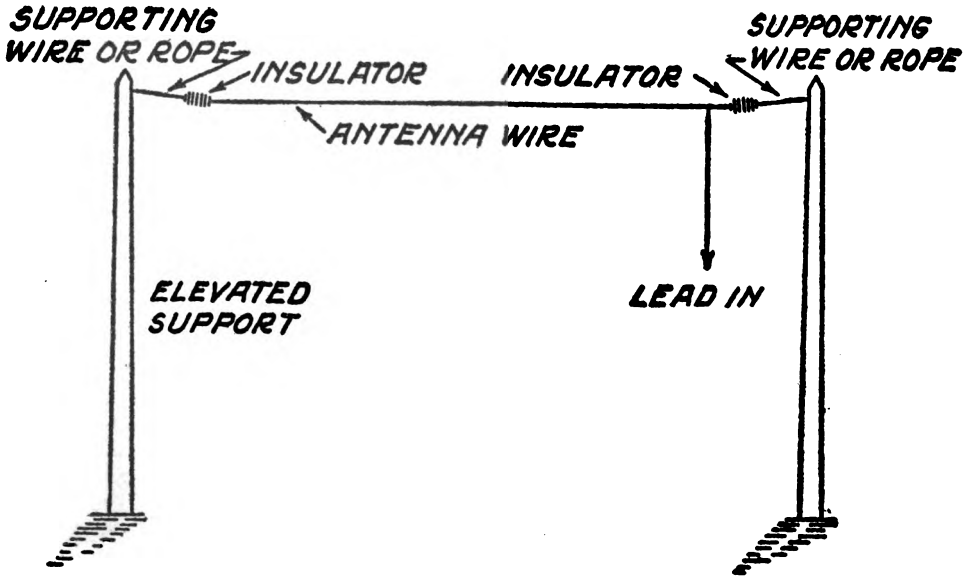

FIG. 24. The inverted L antenna may be used for both transmitting and receiving.

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another insulator, which in turn is fastened to another high structure by means of a rope or wire. The lead-in wire is then joined to one end of the antenna wire and soldered. This wire is then led down to the radio instruments, care being taken that it touches no other objects on the way down. If more than one wire is used in the antenna, a wooden "spreader" is used to keep the wires the correct distance apart, as shown in Fig. 25. Each end of each wire has an insulator attached. The wires should not be spaced closer than 2 feet apart. The L antenna is fairly directional and if possible should be pointed so that the end of the antenna from which the lead-in is taken off, points in the direction that it is desired to receive from most efficiently.

2. The T antenna is constructed in the same manner as the L antenna with one modification. Instead of the lead-in being taken from one end, it is taken from the exact center of the antenna. This gives it the shape of the letter T. The T antenna can be used for both transmission and reception, but it is mostly used for transmission. It has the same capacity to ground as the inverted L antenna, but it has only one-half

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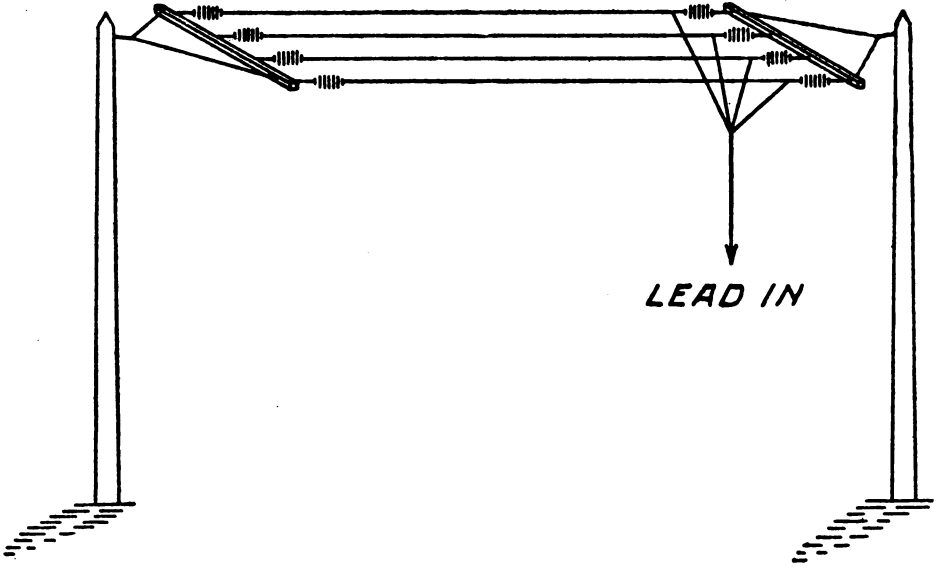

FIG. 25. The 4-wire inverted L antenna. The wooden "spreaders" keep the wires the correct distance apart. Two insulators are used on each wire, one at each end.

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the distributed inductance. It is directional in both directions, toward each end.

3. The umbrella type of antenna is con-

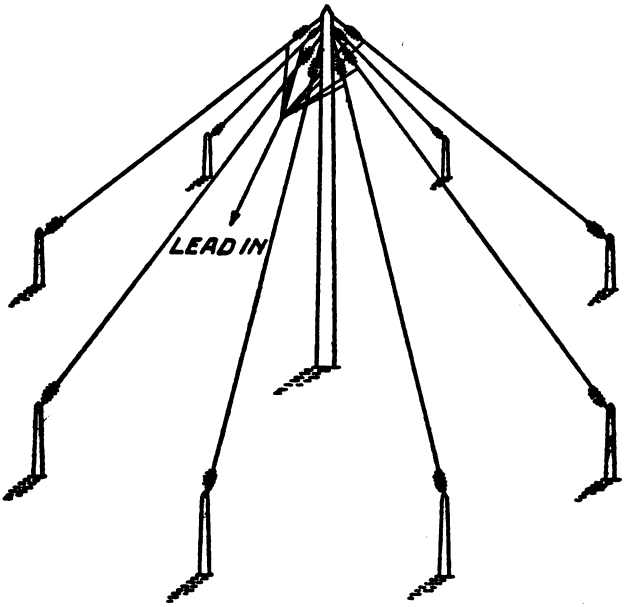

FIG. 26. The umbrella antenna is non-directional. The lead in wires are connected at the center.

structed by placing a number of low supports in a circle with a high support in the center of the circle. Radiating antenna wires are then strung from the center support to the other

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supports insulated at each end, with the lead-in wires attached at the center (see Fig. 26). This type of antenna is non-directional, or transmits

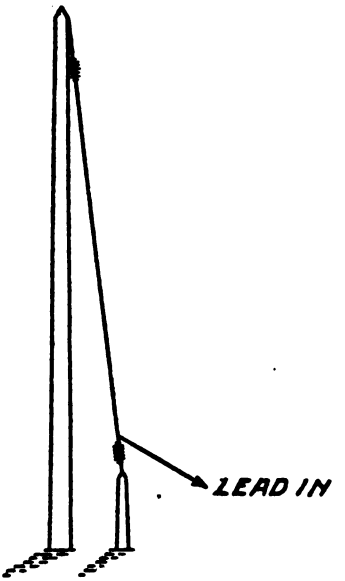

FIG. 27. The vertical antenna consists of one wire strung to a high support at one end and insulated at both ends.

and receives equally well from any direction. It is limited in use for amateurs, however, because of the expense and the large area that it takes up.

4. The vertical antenna is a wire or wires

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stretched vertically up to a high support with the lead-in at the bottom (see Fig. 27). This antenna is also non-directional, but is not much used for transmitting on account of its low capacity to ground. It makes a very good antenna for receiving, on account of its simplicity and non-directional characteristics.

5. The fan antenna is like the L type antenna except that the wires at the far end of the antenna are spread out so that it takes the shape of an open fan (see Fig. 28), with the lead-in at the point of the fan. This type is good for both transmitting and receiving, as it is less directional than the L type.

6. The cage type of antenna can be made into any of the above-mentioned types of antennae. It consists of using a number of strands of wire arranged in a circle instead of the single strand; each wire of the cage antenna is fastened to a number of metal rings which support the wires in the form of a tubular cage (see Fig. 29). The use of the cage form of antenna is becoming very popular and its advantages are: the stresses due to high voltages are much reduced, due to the added surfaces, the capacity of such an antenna is higher than the ordinary

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antenna of single wires, and each wire carries approximately the same voltage charge. The cage antenna does not require any spreaders. The usual size of the rings used for cages is

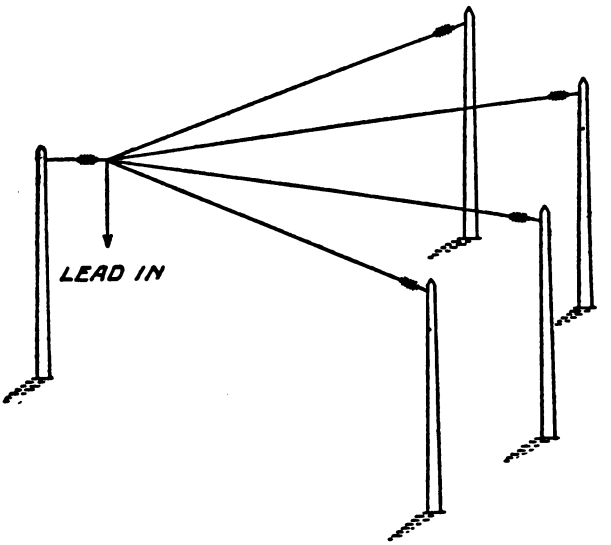

FIG. 28. The fan antenna, so-called on account of its shape.

eight inches in diameter, but larger or smaller diameter rings may be used with gratifying results.

With all types of capacity antennae, there are certain things to be remembered in respect to

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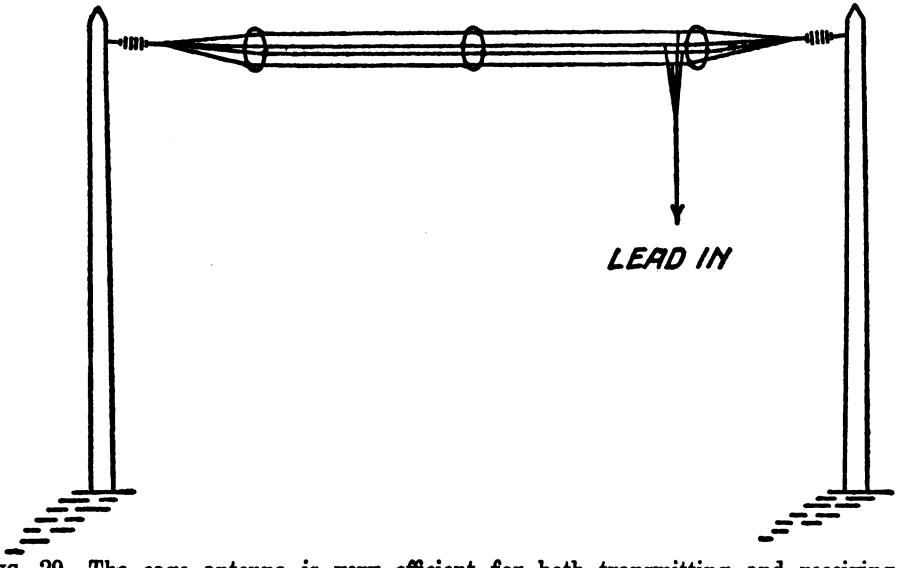

FIG. 29. The cage antenna is very efficient for both transmitting and receiving. The wires are supported in a tubular formation by metal rings.

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construction, which are of the utmost importance to those who intend to install a radio set, for either receiving or transmitting. The antenna should be erected as high as possible and free from obstruction from all other objects such as trees, buildings, metal objects, hills, etc. The wires should not run closer than 20 feet to any metal roofs, or branches of trees, or fire-escapes. If there are any high tension transmission lines nearby, or any telephone lines or trolley lines, the antenna should be run at right angles to them, to eliminate induction noises that would otherwise interfere with reception. Be sure that the antenna wires do not touch any object and thus short circuit to ground. It is not a good plan to run the antenna wires across any other wires such as high voltage lines because of the possibility of the antenna wires breaking and falling across the other wires and carrying the high voltage currents down to the set where it might do bodily harm to a person listening at the apparatus. All connections should be soldered. Large commercial antennae are usually constructed of silicon bronze wire, but for amateur use bare stranded copper wire is recommended.

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The magnetic form of antenna consists of various shaped coils or loops as they are better known. Loop antennae are very directional and for this reason are used in most forms of

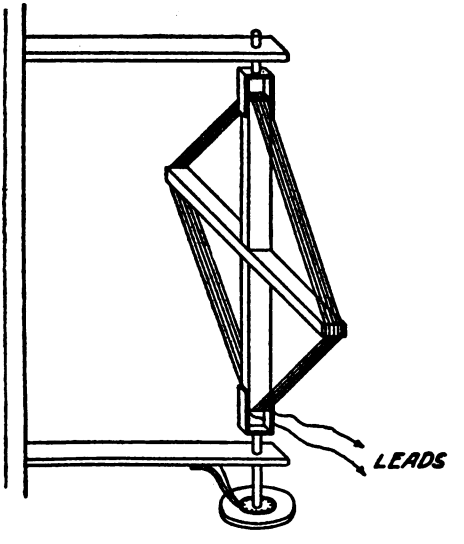

FIG. 30. The loop antenna may be turned on its axis by means of the wheel at the botton in order to "tune in" signals from different directions.

direction finders. The loop antenna consists of a number of turns of wire wound on a cross-arm, the number of turns depending on the wavelength that the loop is designed to receive

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on. A picture diagram of a loop antenna is shown in Fig. 30. The loop antenna receives signals in two directions, at right angles to its plane. Thus by turning the loop upon a vertical axis we can tell if a signal comes from the north or south or from the east or west of the point where our station is located. If we take observations from two points at the same time we can tell the exact location of the transmitting station by plotting the directions on a map. The point where the two lines cross, that we have drawn as directions, will be the location.

Some other forms of loop antennae give the direction of the transmitting station in the one correct direction only, and it is recorded on a dial graduated in degrees. A small pointer attached to and revolving with the loop accomplishes these results.

A loop antenna does not require any ground and can be used inside a building or underground. It can be made non-directional, however, by placing it horizontal to the ground. All forms of loop or coil antennae require more amplification than the ordinary capacity form of antenna because the signals are much weaker and must be strengthened to the requisite

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amount so that they can be easily heard by the listener. A loop antenna is not practical for use with a crystal detector for this reason.

One great advantage of the loop is that if two stations are transmitting on the same wavelength and they lie in different directions from the receiving station either one of these two stations may be tuned in or out by merely revolving the loop, whereas with the capacity type of antenna they would both be received and would interfere with each other.

Loop antennae are used by the Navy for direction finding at sea, and by the United States Signal Corps for location work for aeroplanes flying by night and for location of landing fields by radio from an aeroplane. The radio inspectors of the Department of Commerce use the loop antenna for locating transgressors against the radio laws and regulations of the United States and for locating unlawfully operated stations. A loop antenna can be mounted on an automobile or truck and in the case of locating a certain station that is transmitting, the automobile can be driven to a certain location and directional readings taken on the station's signals and the direction plotted

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on a map. The next step would be to move the automobile in a direction at right angles to the direction that the signals came from and take another reading of the direction of the signals, and plot this direction on the same map. The point where the two lines cross is the location of the transmitter in question. The accuracy of the newer types of directional antennae and associated apparatus is quite marvelous and is one of the chief aids to navigation for the modern mariner. One ship captain in a recent report on the apparatus installed on his ship stated that in one case when he had lost his bearings due to a very intense fog, he ordered the radio operator on his ship to get the location of a certain lightship. This the operator did and gave his report to the captain. The captain then headed his ship in the direction of the lightship as recorded by radio and after three hours' run had to suddenly change the course of the ship to avoid cutting it in half.

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CHAPTER VI

TUNING APPARATUS FOR RECEIVING

THERE are a number of different types of oscillating circuits used in radio telegraphy and radio telephony, for both transmitting and receiving. We have learned that to tune an oscillating circuit to a given frequency, we may vary the capacity of the circuit or the inductance of the circuit. This means that we use a variable condenser or a variable tuning coil to accomplish this change in frequency or wavelength.

The type of oscillating circuit that we have studied up to this point is one that is used in connection with the production of high frequency currents. We shall now study oscillating circuits that are used to collect or receive high frequency oscillating currents. But first of all we must learn something about the electrical device called a "transformer." A transformer of electrical energy is used for a number of different purposes. One use is to trans-

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fer alternating current energy from one circuit to another. Another use is to raise the voltage of an alternating current, thus stepping it up. The third use that the transformer can be put to is to reduce the voltage of an alternating current.

Primarily, a transformer consists of two parts; the primary coil or winding and the secondary coil or winding. If an alternating current is caused to flow in the first winding, an alternating magnetic field is set up around this coil. If the second coil is placed in inductive relation with the first coil, the magnetic field generated about the first coil will pass through the windings of the second coil and cause the same kind of alternating current to flow in the secondary winding. If the number of turns in the secondary winding are the same as those in the primary winding, the voltage in the secondary will be the same as the voltage in the primary circuit. If the number of secondary turns of wire should be double the number in the primary, the voltage in the secondary will be twice that in the primary. In other words, the voltage induced in the secondary of a transformer will be proportional to

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the voltage in the primary, multiplied by the ratio of the secondary turns to the primary turns.

By placing primary and secondary coils in inductive relation, is meant arranging the two coils so that the axis of the coils will be in the same line. Sometimes the coupling of coils is varied, by making one of the coils rotate on its axis and in other cases one coil slides in and out of the other coil. In Fig. 31A, two coils are shown placed in inductive relation with each other. In Fig. 31B, the two coils are shown in non-inductive relation. In this position very little current can be induced in the secondary from the primary winding.

In the vacuum tube oscillating circuit, energy in the oscillating circuit is sometimes transferred to the antenna circuit by means of such a transformer as described. In other cases only one coil is used, this coil serving the purposes of a primary and a secondary combined. The antenna circuit in this case is a separate oscillating circuit, although electrically connected to the vacuum tube oscillating circuit.

Now let us suppose that we have one of these transmitting vacuum tube outfits sending out

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a radio wave, and we wish to tune a receiving antenna so that the radio wave will induce

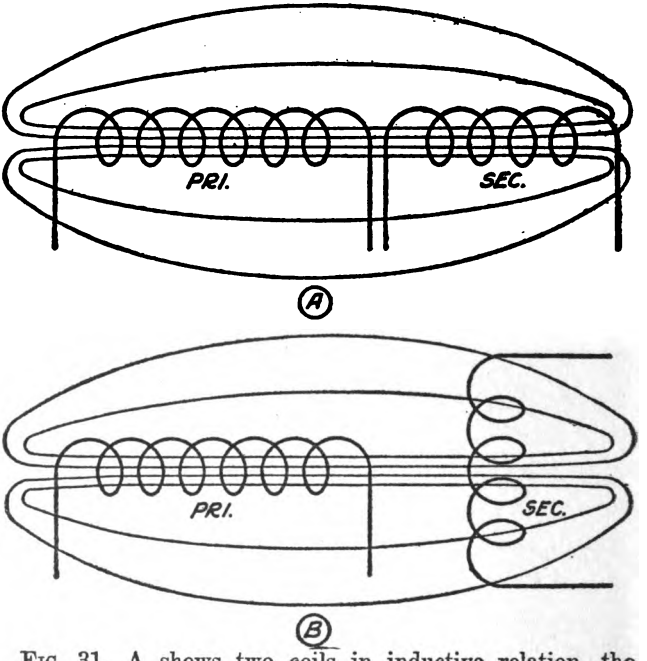

FIG. 31. A shows two coils in inductive relation, the magnetic flux flowing through both coils. B shows the two coils in non-inductive relation, the magnetic flux flowing only through one coil.

currents in the receiving antenna. To do this, we must have either a variable condenser or a variable coil in the receiving antenna circuit,

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and upon varying either one or both of these, we can tune the receiving antenna circuit to the same frequency as the transmitting antenna circuit, and when this is tuned, the radio waves will

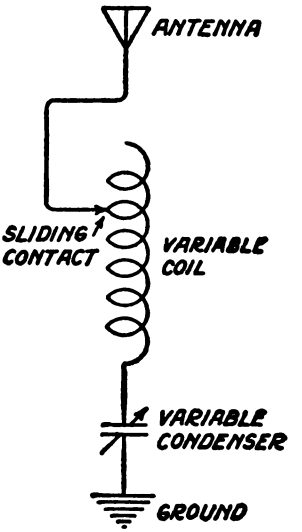

FIG. 32. A simple "tuned" antenna circuit. Tuning is accomplished by varying either the inductance or the capacity of the circuit.

induce currents in the receiving circuit. A tuned antenna is shown in Fig. 32. The inductance of the coil is varied by cutting in or out of the circuit a number of turns of wire by means of

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a contact known as a slider, which touches one turn of wire at a time. The variable condenser consists of a number of semi-circular, flat stationary plates which are separated from each other, and having in between them a number of rotating plates which revolve in the spaces between the stationary plates without touching them. This makes two sets of plates separated by an insulating air space.

By rotating the plates we vary the amount of surfaces of these plates exposed to each other and thus vary the electrical capacity of the condenser.

By increasing the capacity of the condenser (by turning the knob and dial) we raise the wavelength that the circuit responds to. We can also do the same thing by adding to the number of turns on the coil. This process is called "tuning." A simple tuned circuit as shown above will respond to a number of wavelengths at the same time, or in other words, it tunes broadly. This is a disadvantage as instead of listening to one station at a time we may be compelled, on account of this "broad" tuning characteristic of the single tuned circuit, to listen to two or three at the same time,

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and we will have a hard time to distinguish what is being sent out by the station we wish to listen to.

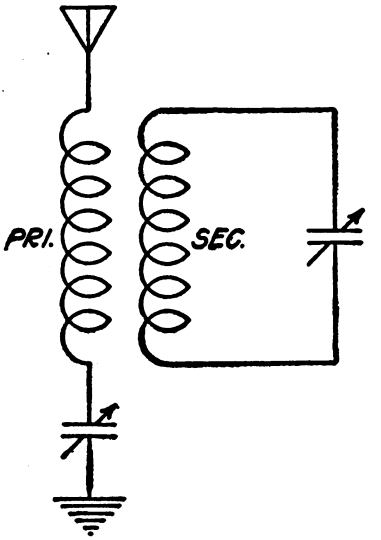

FIG. 33. A primary circuit and a secondary circuit, each tuned to the same wavelength by means of variable condensers. The primary and secondary coils form an instrument called a loose coupler. This instrument transfers the electrical energy from the primary circuit to the secondary.

A more recent development for tuning is shown in Fig. 33 and employs the same tuned antenna circuit, but uses the coil as the primary

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winding of a transformer which transfers the high frequency currents which flow in the antenna circuit to another circuit called the secondary circuit. Of course the transformer has a secondary winding in which the current is induced from the primary winding. This secondary circuit must be tuned to the wave-length of the incoming current also, and for this purpose another variable condenser is connected across it. The secondary coil is usually arranged so that its magnetic field may occupy the same space as the field of the primary coil, or be varied in position so that it occupies only a part or none of the same space. This is called varying the coupling between the coils.

With this system of tuning, called double circuit tuning or inductively coupled tuning, a much greater degree of selectivity is obtained, as the signal has to pass through two tuned circuits which act as sieves and let only the one size or length of wave through. This type of tuning transformer was known formerly as a loose-coupler, but it has been improved and is now known generally by the name of vario-coupler.

There are other circuits which have been used

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more or less, which go as far as three circuits, but there are so many things to tune and so many knobs to turn that it takes too long a time to tune in a signal and therefore their use has

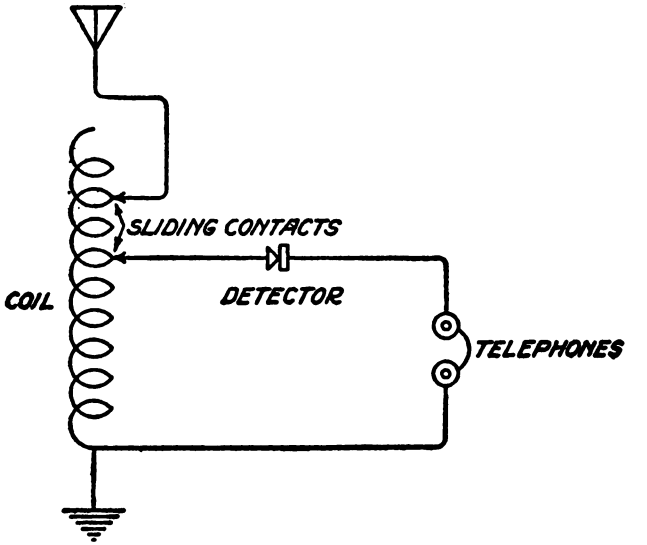

FIG. 34. Double slide tuner connected to a crystal detector and telephones.

died out, even though some of them were more selective than the double circuit tuning.

One circuit that we might mention uses two circuits for tuning, but uses only one coil, the coil serving the double purpose of a primary

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and a secondary at the same time. This coil is called a double slide tuner and a circuit showing it hooked up to a crystal detector and a pair of telephones is shown in Fig. 34. One slider tunes the primary circuit and the other slider tunes the secondary circuit. This is known as a conductively coupled circuit because the two circuits are joined conductively by the same coil of wire which serves in each of the two circuits.

As mentioned previously, coils are varied by cutting in and out of the circuit a number of turns of wire on the coil. This changes the magnetic field around the coil. The magnetic force surrounding the adjacent turns of wire on a coil produce a result in the coil itself that is called "mutual induction," and mutual induction really means the amount of magnetic energy that a coil can store up.

If a coil should be cut in half, and one-half of the coil turned around, and the wires rejoined to the other half of the coil, and a current passed through the coil, the magnetic field through one-half of the coil would buck the magnetic field through the other half of the coil (see Fig. 35A). In this way the two fields would

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neutralize each other and the coil would have approximately zero mutual inductance or, in other words, it could store up no magnetic energy at all. If the half of the coil that was

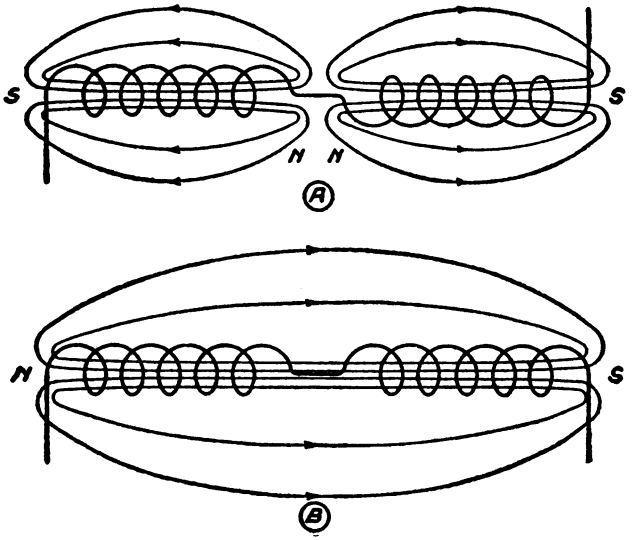

FIG. 35. A—Two coils shown connected, opposing
B—Two coils connected, additive.

reversed be revolved so that its field is in the same direction as the other field the coils will have maximum mutual inductance, and will be able to store up quite a large amount of

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magnetic energy (see Fig. 35B). Another way of stating this effect is to say that with the coils opposing, the coils have a low wavelength, and with the coils additive, the coils have a higher wavelength. We see now that this arrangement gives us a very fine method for tuning, as all we have to do is turn one coil of the two and the wavelength of the combined coils increases continuously without any jumps or steps, as in the event of using a slider or a tapped coil. This type of tuning instrument is called a variometer. A circuit (Fig. 36) shows how two variometers can be used in connection with a loose coupler to vary both the primary wavelength and the secondary wavelength of a tuning system. The wavelengths of both circuits can be controlled by merely turning one coil of each of the variometers. The coils of the loose-coupler are fixed and do not need to be varied at all.

All of the various tuning circuits employ one or more of the instruments described. The names of these instruments will be repeated here for reference. For use with single tuned circuits: single slide tuning coil, variometer and variable condenser. For double circuit tuned

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systems: double slide tuning coil, loose-coupler, variocoupler, variometer, and variable condenser. These tuning instruments can be

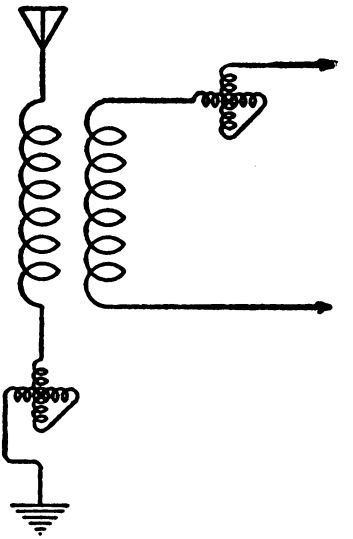

FIG. 36. Circuit showing the primary and secondary wavelengths "tuned" by variometers.

arranged in numerous ways and in numerous combinations to produce tuning systems that have each their advantages and disadvantages.

We will now go on with the study of the detector for rectifying the currents after they have been received for making them audible.

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If we were to connect a pair of telephone receivers across the secondary terminals of a loose coupler connected up to condensers and an antenna, as in Fig. 33, we would hear nothing, for the current is of too high a frequency to work the telephone receivers and must first be changed to a direct current. This is accomplished by a device named a "detector."

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CHAPTER VII

THE CRYSTAL DETECTOR AND THE VACUUM TUBE

SINCE the days when radio communication was first conceived, the apparatus used for rectifying the high frequency currents received in an antenna system in order to change these currents into a pulsating direct current, has been improved and new apparatus has been developed. The efficiency of detecting apparatus has been increased enormously.

Marconi's coherer and decoherer, which consisted of a glass tube filled with iron filings with a terminal at each end, is long ago out of date. But we will give a simple explanation of how it works, as a point of interest. It was found that when a high frequency current was caused to pass through a column of these small filings, the filings would turn and join end to end, thus forming a contact with each other and making the tube conductive to a direct current which could flow through it. The decoherer consisted of an ordinary electrical buzzer with a vibrating

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"tapper" connected to it, which tapped on the glass tube and broke the contact between the small pieces of filings. This was necessary because once the filings formed a circuit they would stay that way, and it was necessary to break up the circuit, so that the dot and dash impulses could be received by the regular telegraph sounder. A coherer and decoherer could never be used for telephony, and are very crude devices. Marconi later developed a form of detector called a magnetic detector which was much more sensitive, a description of which would be too lengthy to give here.

Later it was found that certain minerals or crystal formations possessed the ability to allow current to flow through their substance in one direction, but not in the other direction. This characteristic of certain forms of crystal is called their uni-lateral conductivity. The carborundum crystal is used in a circuit with a special contact-making device and attached to a battery and potentiometer, as shown in Fig. 37, was found to have this characteristic to a marked degree.

The potentiometer is a variable resistance for supplying the correct potential or voltage to

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the crystal to make it operative. It may be stated here that certain crystals require a battery current to increase their sensitivity, while other crystals need no battery at all. Such

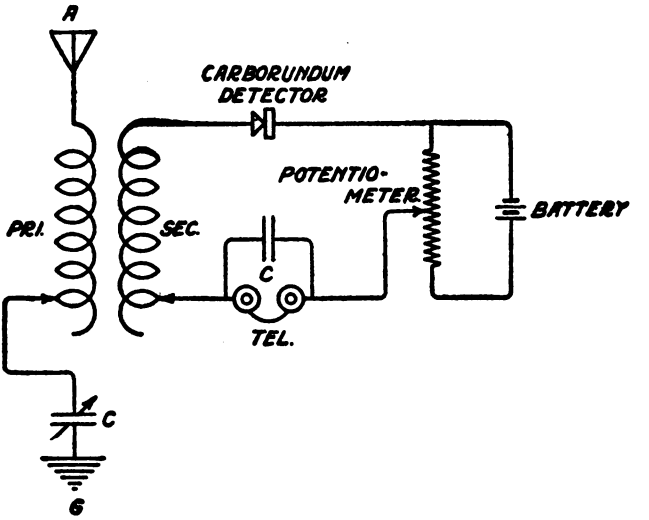

FIG. 37. Circuit employing a carborundum detector, loose coupler, variable condenser C, potentiometer, battery and telephones, with a small fixed condenser C connected across the telephones.

a crystal as last described, which is slightly more sensitive than the carborundum crystal, is "silicon." The silicon crystal is fastened in a metal cup-shaped container and held tight

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with metal screws. The crystals are not sensitive over their entire surface, but only in spots. In order to adjust a crystal detector, a variable moving contact which is sometimes constructed in the shape of a spiral spring, attached to a

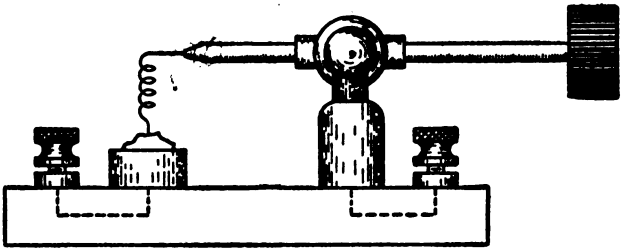

FIG. 38. Mounting for a crystal detector showing the two terminals, the adjusting rod and spring, and the crystal cup.

rod that is mounted on a universal joint so that it can be moved in any direction, is used. Such a crystal mounting with an adjustable contact is shown in the picture of Fig. 38. In the case of the silicon detector the tension of the spring is greater than with other forms of crystals. The type of crystal detector which is becoming most popular and is used almost universally is the Galena crystal. This crystal is mined and is usually found in the vicinity of lead, tin and coal fields. For use with Galena

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the adjusting spring is very light and flexible, as Galena requires a very light contact. Galena is a little more difficult to adjust than the other crystals, but when adjusted it will be found to be much more sensitive. When a current is received in the primary circuit of a loose coupler and this energy is transferred to the secondary circuit, the wave form is oscillatory, as indicated in the diagram of Figure 39A. As stated before, the frequency of these little impulses is so great that the impulses could not be heard, and they must be rectified or changed into a direct current before they will cause the telephones to operate and change the electricity into sound. In Fig. 39A we have the alternations numbered for reference. All the positive alternations having uneven numbers and the negative having even numbers. These alternations being of opposite polarity and following so quickly one after the other produce no effect upon the telephones on account of their opposite polarity and speed of vibration, but if we could strike out either all of the positive or all of the negative alternations, leaving only one set of positive alternations, the impulses would add up upon each other and

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cause the diaphragm in the telephone to be attracted toward the magnets in the telephones.

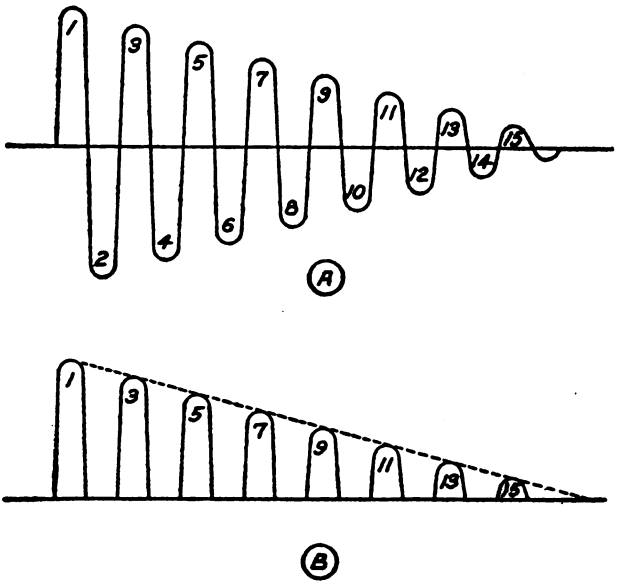

FIG. 39. A shows the received electrical oscillations. B—Rectified impulses, which add up upon each other, making one large impulse, as shown by the dotted outline.

This would cause a single sound wave or impulse to be generated in the telephones.

The crystal detector does just this thing; it allows only the positive alternations to flow through the circuit and prevents the negative

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alternations from doing so. This results in a series of positive alternations flowing through the telephones as necessary to cause the phones to operate (see Fig. 39 B).

It should be remembered that in order to receive signals with a crystal detector circuit, all the circuits used must be tuned to the wave-length of the incoming signals and the crystal detector must be adjusted to sensitiveness. It is easy to adjust a crystal detector by means of the little contact spring when all of the circuits are already in tune with some transmitting station and if a transmitting station happens to be transmitting at the time, but if there are no stations transmitting it would be difficult to know whether the crystal were in adjustment, or not. We would not know whether the crystal was out of adjustment or whether it just happened that there were no stations transmitting at the time. There is a method for adjusting a crystal detector, and the combination of instruments used for this purpose is called a "buzzer test." A buzzer test consists of the following instruments: a small high pitched buzzer, one dry cell, a push button and some wire. The terminal of the buzzer is

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connected in series with the battery and the push button. A diagram of connections of a loose coupler with a crystal detector and a pair of telephones connected with a buzzer test is shown in Fig. 40. To adjust the detector to

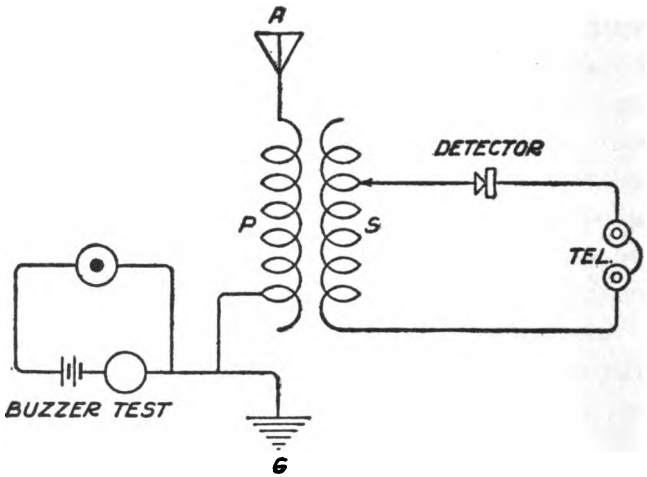

FIG. 40. Buzzer test connected to the crystal receiving set to help adjust the crystal to sensitiveness.

sensitiveness all that is required is to press the button and make the buzzer buzz, place telephones over the ears and adjust the little contact spring on the crystal until the buzz is heard loudest in the telephones. The crystal

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is then "in adjustment." The push button can now be released and the sliding contact on the primary coil adjusted and the taps on the secondary coil adjusted, together with an adjustment of the coupling between the coils. This is all that is necessary to tune in signals with a crystal detector. Once signals are being received steadily the operator may even readjust the crystal detector to bring the signals still louder. The crystal detector sets will receive with a range up to fifty miles with a good antenna and under good conditions, but occasionally greater distances than this are covered.

The vacuum tube also may be used as a rectifier or detector of high frequency electrical oscillations and when connected up to the proper circuit it does this with a much greater efficiency than the crystal detector.

The vacuum tube when connected up to a tuning device and used as a detector or rectifier of electrical oscillations such as those induced in radio receiving apparatus by distant transmitting apparatus, will perform its duties with a high degree of efficiency and with uniform sensitivity. The only adjustments

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necessary are the adjustment of the filament current, thus controlling the electron emission from the filament, and the adjustment of the plate voltage which also tends to control the electron emission. It will be remembered that it is this electron stream that causes the tube to function and repeat in its plate circuit in magnified and rectified form, the weak high frequency currents which are induced in the receiving apparatus when the set is properly tuned to the wavelength of the incoming signals.

Such a circuit using the vacuum tube as a detector is shown in Fig. 41, where the resistance R is used to control the filament current and the "B" batteries are tapped between cells so that the correct voltage may be applied to the tube. The correct voltage for the plate circuit is usually found by experiment as different tubes use different voltages on the plate circuits for their most efficient operation. The correct voltage can be readily found once a signal has been tuned in by listening to the signal while varying the tap to the battery. The tap which gives the loudest results is the correct one. This adjustment may be made once and then set, as there is nothing to be gained by making changes

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unless the "B" battery begins to weaken. "B" batteries usually last from six months to a year before any weakening is experienced.

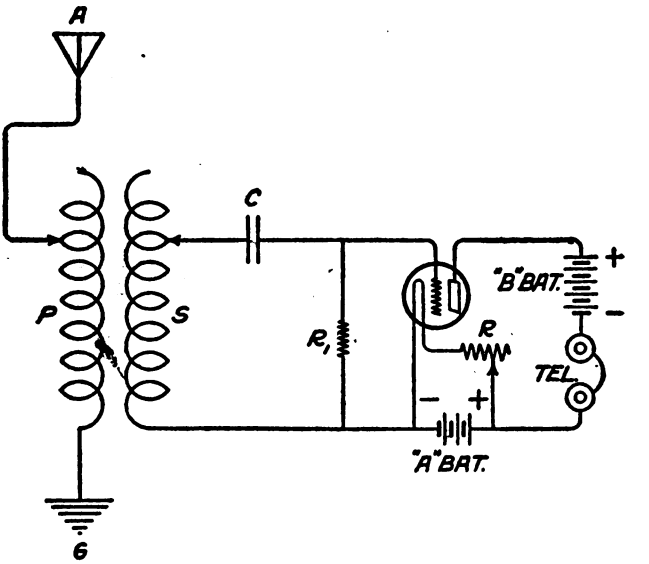

FIG. 41. Vacuum tube used as a detector in a radio receiving circuit.

The condenser C is used to collect the charges due to the incoming oscillations and apply them to the grid of the tube. The resistance R1 is used to prevent the charges impressed on the condenser C from becoming too large so that

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they make the tube inoperative. This resistance is termed a "grid leak," and it allows the excessive charges to leak off the grid condenser to the filament circuit where they can do no harm.

The vacuum tube when used as a detector never varies in its sensitivity, and as its inherent sensitivity is so much greater than the crystal detector without the disadvantages that are connected with the variable sensitivity of the crystal it has grown to be the standard as a radio detector and its use is almost universal. Crystal sets are still sold to beginners and those who live very close to broadcasting stations and do not wish to bother with the batteries necessary for use with the vacuum tube detector.

For long distance receiving, however, it is imperative to use the vacuum tube type of detector if persistent and regular results are to be obtained.

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CHAPTER VIII

REGENERATION AND AMPLIFICATION

THE vacuum tube detector, as shown in the last chapter, is undoubtedly the most sensitive detector as yet devised, but a new circuit has been discovered to be used with the vacuum tube which makes the tube self-amplifying, so that the signals may be greatly increased over and above the strength that they really have upon being received.

This circuit is generally known as the regenerative circuit and relies for its action upon the fact that a vacuum tube when hooked up to a special circuit will generate oscillations whose frequency can be controlled by varying the capacity or inductance of the circuit. The man who discovered this action and invented the circuit is Edwin H. Armstrong and in doing so he has contributed what is universally acclaimed the greatest and most important invention since radio was first conceived. Since the invention of the regenerative circuit he has

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developed and perfected other inventions pertaining to vacuum tube circuits that undoubtedly place him in the first place as far as research work on vacuum tube circuits is concerned.

Now, to learn a little more about the regenerative circuit and what it does. We have learned that if we impress a feeble alternating on the grid circuit of a vacuum tube, the current will be changed or rectified into a much stronger pulsating direct current whose pulsations exactly resemble the oscillations of the feeble incoming current. Now, suppose that in some manner we could feed back into the grid circuit, some of this current of increased strength which is caused to flow in the plate current. Roughly, what would happen would be a much greater impulse flowing in the plate current as a result. This is what Armstrong discovered: that if he put an inductance in the plate circuit of the vacuum tube he could tune the plate circuit up nearly to the wavelength of the secondary circuit and thus feed back some of the energy from the plate circuit to the grid circuit, and thus, by increasing the grid voltages, cause a much greater current to flow in the plate circuit

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than would ordinarily flow from the feeble incoming voltage without regeneration.

There is one thing to be remembered in connection with this circuit, however, and that is if the plate circuit is tuned to exactly the same wavelength, the amount of current fed back into the grid circuit will be sufficient to cause the tube to generate oscillations and thus distort the incoming signals. The inductance in the plate circuit should be increased therefore until the circuit begins to oscillate and then be reduced slightly, so that the signals will be amplified without distortion. The point of maximum amplification will be found to be just under the point where the circuit oscillates.

Armstrong's first circuit is shown in Fig. 42. This shows the vacuum tube connected up with a loose coupler and also shows the tuning inductance in the grid circuit, variable by means of a slider.

Another type of plate load that is used widely in short wave tuning receiving sets was first designed by Paul Godley, who conducted the receiving tests at Androssan, Scotland, with the American amateurs who were striving to transmit across the Atlantic Ocean. It is now a

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matter of history, as to how many of our American boys were heard by Godley in Scotland. The circuit uses a variocoupler, two variometers, and the vacuum tube associated

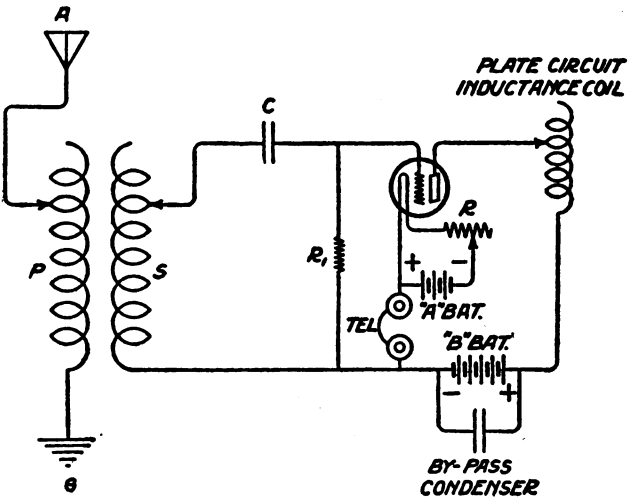

FIG. 42. Armstrong regenerative circuit.

apparatus, and is shown in Fig. 43. One variometer is placed in the plate circuit to control the regeneration, and the other is placed in the secondary or grid circuit to tune the secondary circuit. The coupling between the primary and the secondary coils of the variocoupler is

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varied by revolving the secondary coil which is mounted on a shaft which turns in bearings. The wavelength of the primary or antenna circuit is varied by means of taps and a rotating switch arm.

The proper way to tune a regenerative

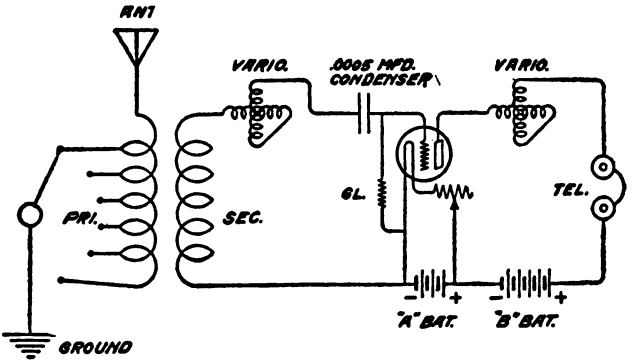

FIG. 43. Diagram of a regenerative set using a variocoupler and two variometers.

receiver is to set the regeneration control at zero (lowest value of inductance), then set the coupling at maximum (coils in inductive relation). The next step is to tune the antenna circuit by moving the switch arm, then rotate the grid variometer till the signal is picked up. The coupling can now be loosened till the signal

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begins to get weaker, when the grid variometer is again adjusted and the signal again increased in strength. The regeneration control is then brought into play and rotated until the signal is brought to maximum strength without distortion. A slight readjustment of the grid variometer will get the most out of the self-amplifying circuit that it is possible to obtain.

Another way to obtain regeneration in a receiving circuit is to place a coil in the plate circuit which is in inductive relation with the secondary coil of the tuner, or loose coupler. This circuit is known as the tickler feed back circuit and the plate coil is called the "tickler." The tickler is rotatable, so that the amount of current fed back into the grid circuit can be varied. This circuit is more efficient on high wavelengths and is generally used with a type of fixed inductance coils, known as "honeycomb" coils, with a variable condenser in series with the primary coil to adjust the antenna circuit wavelength, and a variable condenser connected across the secondary coil to adjust the wavelength of the secondary circuit (see Fig. 44).

Another simple but less efficient way to

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obtain regeneration is to connect the secondary terminals of the tuner to the grid and the plate of the tube, as shown in Fig. 45, instead of the conventional way of connecting them to the grid and filament of the tube. This will cause regeneration, but the tube oscillates in an unstable manner and is very hard to control.

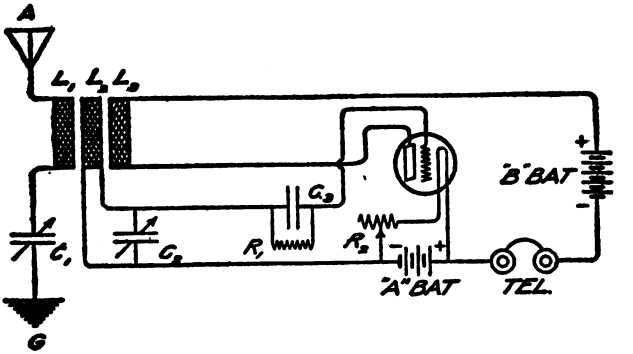

FIG. 44. Regenerative set, using honeycomb coils. L1 is the primary coil, L2 is the secondary coil, L3 is the tickler used for regeneration control. Tuning is accomplished by the use of the two condensors, C1 and C2.

The circuit is generally known as the "ultra-audion" circuit, but its use has fallen off in favor of the more efficient and more easily controlled circuits. The small condenser shown connected across the "B" battery in Figs. 42

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and 45 is to by-pass the high frequency currents around the battery.

There are two other methods of amplifying radio signals that we will now consider that

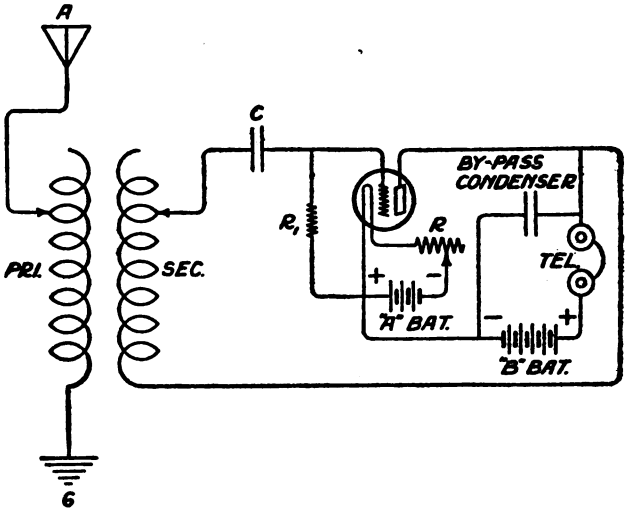

FIG. 45. Ultra-audion circuit.

employ additional vacuum tubes for their operation. They are audio-frequency amplification and radio-frequency amplification. The first amplifies the received currents after they have been passed through the vacuum tube

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circuit and rectified and changed into low frequency pulsating direct currents that become audible when passed through a telephone receiver. In other words, this type amplifies currents of audio-frequency or currents that can be heard when passed through the telephone receivers.

The second method amplifies currents before they pass through the vacuum tube detector. These currents are the high frequency currents that are induced in the antenna and are not audible when passed through the telephone receivers. In other words, these currents are first amplified into stronger radio-frequency currents and are then passed through the vacuum tube detector and telephones and then they become audible, but the amplifying is done at a radio-frequency or high frequency.

We will now go a little more into the details of the audio-frequency amplifier. We have by this time become familiar with the fact that the vacuum tube is a voltage operated device, that is, the higher voltage that we impress on the grid. If we step-up the voltage of the current will flow in the plate circuit. This means that the action of the tube or the

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response of the tube to incoming signals relies on the voltage of the signal that is applied to the grid. If we step up the voltage of the signal by means of a small step-up transformer called an amplifying transformer, the primary winding of which is connected in the plate circuit of the detector tube and the secondary winding of which is connected to the grid of

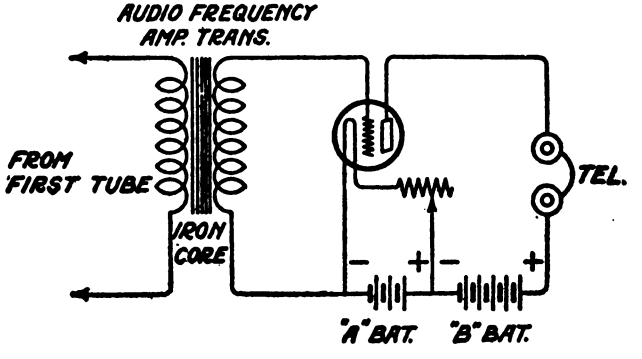

FIG. 46. One stage of audio frequency amplification that can be connected to a receiving vacuum tube set for increasing the strength of received signals.

the second tube, the voltage on the grid of the second tube will be much higher than the voltage on the grid of the first tube (see diagram, Fig. 46). In this way the response of the

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second tube will be greatly increased and the quantity of sound produced when this current is finally passed through the telephone receivers is much greater than would be produced if only one single tube were used.

Each additional tube and amplifying transformer is termed a "stage" of amplification, hence, if we use a detector and one additional tube and amplifying transformer, we call it a detector and one stage amplifier. With this type of amplification we may use as much as three stages of amplification, but beyond this number of stages it is not good practice to go, as the set then becomes so sensitive that all kinds of extraneous noises and squeaks and squawks from the tubes themselves interfere with the incoming signals. A two-stage audio-frequency amplifier attached to a regenerative receiver and vacuum detector is shown in Fig. 47. One set of "A" batteries and one set of "B" batteries are used for all the vacuum tubes. This is a considerable saving over the hook-ups generally given where separate "A" and "B" batteries are necessary.

With two or three steps of this type of amplification signals can be so magnified that they

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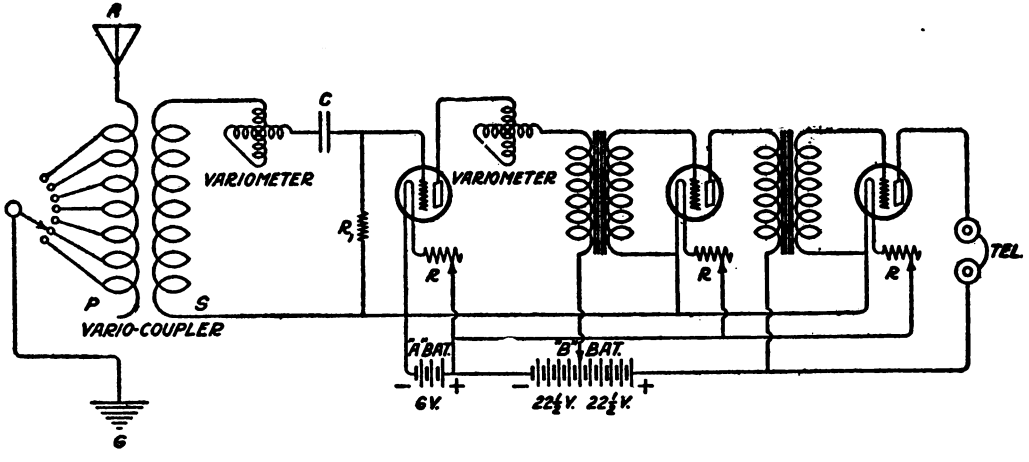

FIG. 47. Regenerative receiver with two stages of audio frequency amplification attached to increase the strength of incoming signals to great volume.

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may be heard in the room without wearing the telephones on the ears, and if connected with a special type of telephone called a loud speaking telephone, the speech signals and music can be heard great distances from the receiving set. For large volumes of sound this method of amplification is probably unsurpassed.

Radio frequency amplification, on the other hand, has its distinct advantages, especially as regards long distance reception. With this type of amplification as stated before, the currents are amplified before they are detected or rectified. However, radio frequency currents can only be amplified to a certain strength with this method. This means that only a certain number of stages of radio frequency amplification will cause a certain signal to be amplified. If we amplify a signal up to a certain strength, by using additional stages we will find that the strength cannot be increased beyond this point. This forms one of the advantages of the system, for a weak signal will be increased by additional stages of amplification, where loud, nearby stations will not be increased at all. In this way radio frequency amplification can be used to eliminate interference from nearby stations and

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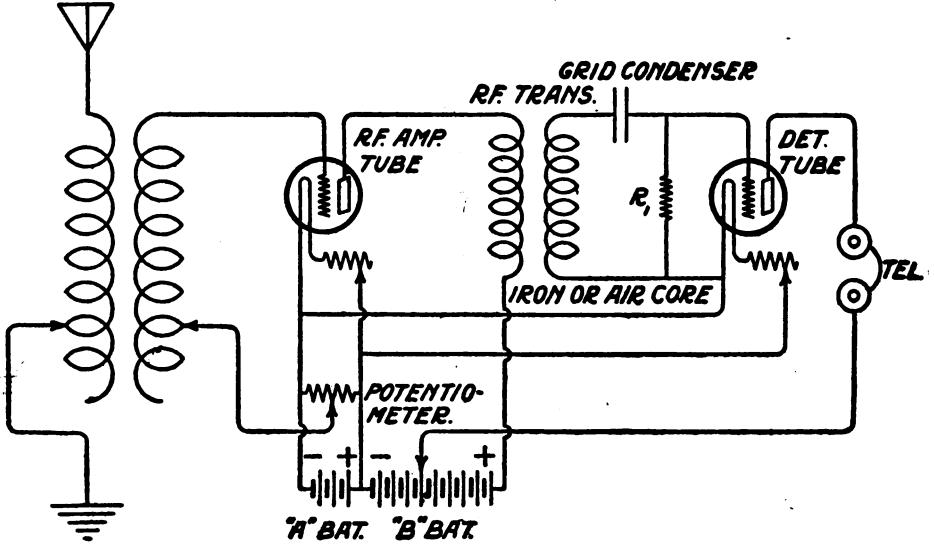

FIG. 48. One stage of radio frequency amplification. The high frequency currents are first amplified and then rectified by the detector tube.

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allow us to listen to distant stations, while the nearby ones are still sending.

Audio frequency transformers will not allow radio frequency currents to flow through their windings, but the radio frequency transformers will allow these currents to flow through them. The circuits of the radio and audio frequency amplification schemes are practically alike, only one scheme deals with high frequency currents and the other deals with low frequency currents. A diagram of a radio frequency amplifier is shown in Fig. 48. An "A" battery potentiometer is used to put the correct voltage on the grid of the tube as the operation of the tube as a radio frequency amplifier is rather critical. The potentiometer consists of a high resistance winding, with a sliding contact that allows any voltage to be picked out and used in the attached circuit.

Radio frequency amplification cannot be used alone with any very good results with a loud speaker, but when two or three stages of audio frequency are used with it, signals can be heard from great distances and will be audible at remarkable distances from the receiving set.

Radio frequency amplification used with a

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loop antenna and a two-stage audio frequency amplifier attached to further increase the strength of the received signals and bring them up loud enough to work a loudspeaker, make the highest type of receiving apparatus that it is possible to obtain (see Fig. 49), as such a receiver will be very selective in tuning and will permit the operator to know from which direction the incoming signals are being sent. Another great advantage of this type of set lies in the fact that no cumbersome outdoor antenna is needed and the whole set can be kept in the living room of a fashionable apartment in a well finished cabinet like that of a Victrola, with the small ornamental loop antenna mounted on the top of the cabinet. The set will then be a thing of beauty and an addition to the furniture of the apartment. The author believes that this type of set will be the final outcome of the broadcast receiver, as when all the people in a big city get interested in receiving it is doubtful if there would be room enough for all the antennae that would be necessary for so many sets. Take the instance of the large apartment house that accommodates 100 families. How on earth would they find room

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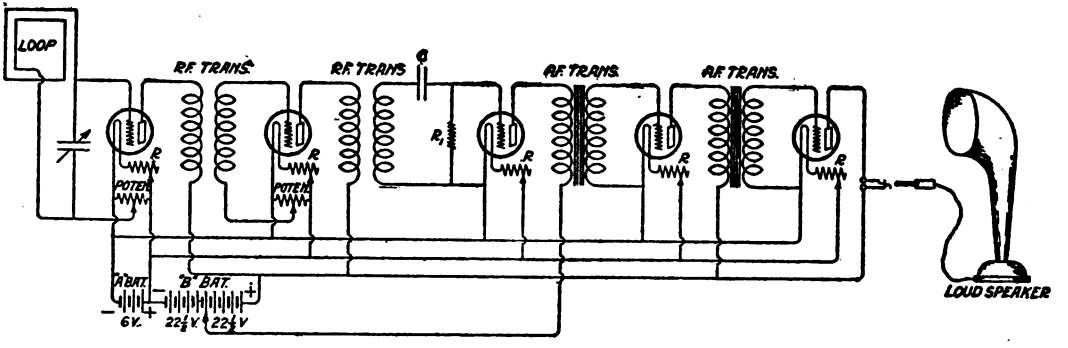

FIG. 49. Two stages of radio frequency amplification used with a loop antenna, detector tube, and two stages of audio frequency amplification and loudspeaker, gives wonderful results.

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to put up 100 antennae on the one house if all became interested. The poor old house would look like a porcupine with all the poles sticking up and out from its exterior surfaces. It would be impossible; besides, what would the landlord say?

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CHAPTER IX

SPECIFICATIONS AND INSTRUCTIONS FOR BUILDING A RADIO TELEPHONE TRANSMITTER

TO the man who is just beginning to be interested in radio and who probably has read no other reading matter than the foregoing chapters of this book, outside of the current monthly magazines, it may seem that this chapter is entirely uncalled for. The average amateur starting in the radio game seems to think that if he can untangle enough data out of the mysteries enshrouding radio, to enable him to build a simple crystal receiver, which by diligent tuning and painstaking adjustment of the crystal will enable him to hear something just once in a while, he is doing fine. But as to building a transmitting set, and worse than that, the most modern and complicated type of transmitting set, the vacuum tube radio telephone transmitter, why the thing is preposterous.

Well, here we go, and if the man has nerve

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enough and is a fair workman, with his head and hands, and follows the directions explicitly, we can guarantee that he will build a set that works and works good. If you do not wish to take the chance, skip this chapter and come back to it later, when you think you have learned a little more.

It will probably be a good idea before going further to review the chapter on the vacuum tube as a generator of oscillations to get the principle of the thing more firmly fixed in your mind. Then come back to this point and we will "dig in" to this stuff together. The author wants the reader to feel that the author is right here at the reader's elbow pointing out the whys and wherefores of the subject to him.

The first thing that we will consider will be the oscillating circuit and how to build the apparatus used and connect it together. There are eleven articles that are necessary to be used for this purpose. We will consider them in turn.

1st. The inductance L1 should be four inches in diameter and six inches long, with 40 turns of No. 14, bare copper wire spaced one-sixteenth of an inch apart. It should have ten taps spaced one tap every turn from the bottom of the

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coil, for the grid voltage control, and ten taps spaced every other turn from the top of the coil for the wavelength control. The remaining ten turns at the center of the coil are left untapped. The tube on which the inductance is wound should be of bakelite, threaded to fit the wire, the groove having about eight turns around the coil to the inch along the coil. The groove can be done in a neighboring machine shop at a very small cost. The wire should be wound in the grooves, as shown in Fig 50, and the taps made as shown in the insert in the same figure. These taps should be staggered on the coil, and when the tube is completely wound the taps should be squeezed together so that the wire will pinch tightly against the tube and bind it to the tube permanently and securely. Wires are then soldered to the taps and brought out to switch points, which can be bought in any radio supply house and fastened on a panel. The two-switch levers shown are mounted on the same panel and make contact with any desired switch point, one at a time. The bottom set of contacts control the grid voltage and the top set control the wavelength it is wished to transmit on, as mentioned before.

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2nd. C1, the grid condenser, consists of two plates of copper foil 1.25 inches square with a connecting flap, and separated by one sheet of mica exactly .003 inch thick, by 1.50 inches

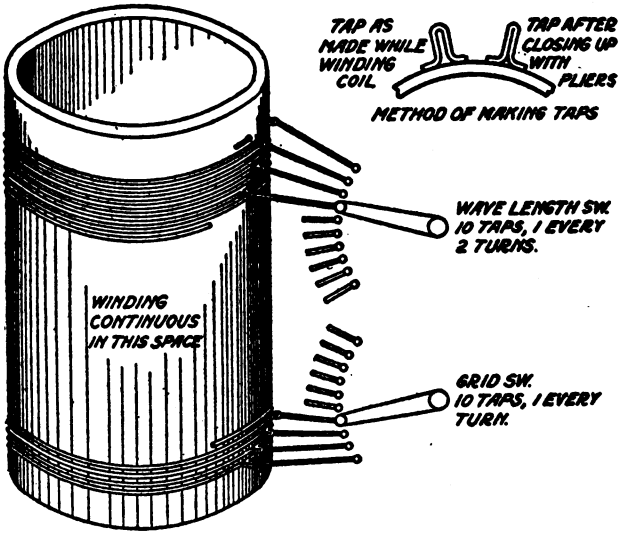

FIG. 50. Inductance coil for transmitting set.

square. The capacity of this condenser will be .0008 microfarads, if made correctly, and too much caution cannot be taken to follow this data exactly. When assembled these plates are clamped together between two thicknesses of

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brass plate on the outside for protection and stability. Of course, one wire is attached to each connecting flap for connecting the condenser in the circuit. If the builder of the set does not wish to make the condensers he can purchase them of the same capacity from the radio supply store. A picture of one of these condensers is shown in Fig. 51.

3rd. C2, the antenna condenser, is similarly constructed as above, except that it has three copper plates instead of two, and these are separated by two sheets of mica. The two outside copper plates are connected together, and form one terminal and the flap on the middle plate forms the other terminal.

4th. The grid leak resistance R2 should have a value of between 5000 and 8000 ohms resistance, and had better be purchased.

5th and 6th. L2 and L3 are two honeycomb coils similar to those used for receiving, and have about 200 turns on each coil and are used as high frequency choke coils.

7th. The vacuum tube can be obtained from the radio store or supply house and the type recommended to the beginner is the 5-watt transmitting tube.

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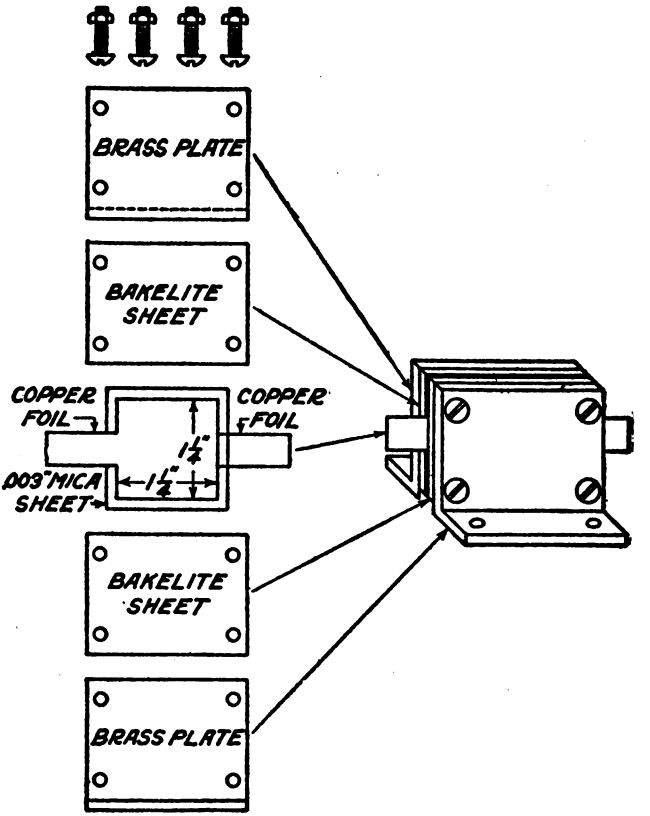

FIG. 51. Showing how to make the mica condensers used in the transmitting set.

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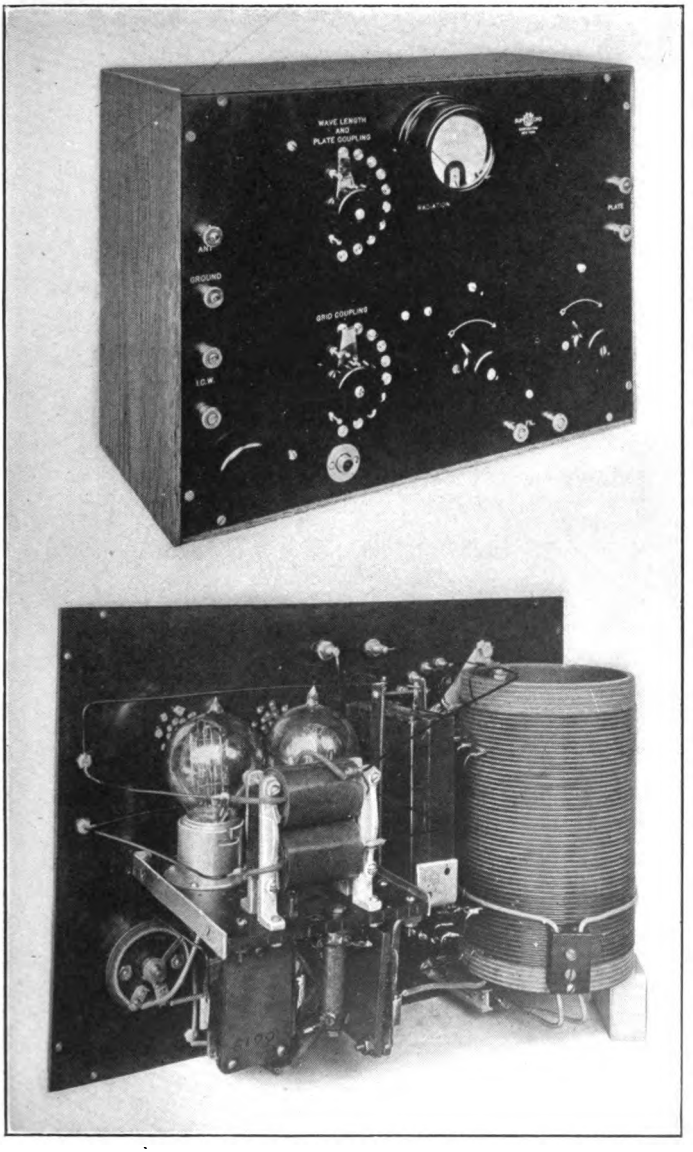

Exterior and interior views of a transmitting radio telephone set, using two 5-Watt vacuum tubes as oscillators and with absorption modulation. Notice the loop of wire around the inductance in the interior view. The microphone is connected directly across this loop for transmitting speech.

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8th. The next part is the tube socket and this also can be purchased. This socket has the necessary terminals for the tube and binding posts attached, so that the tube may be readily mounted without changing connections, or disturbing the wiring.

9th. The filament resistance R1 is for controlling the current flowing through the filament and should have a current carrying capacity of 2.5 amperes and a resistance of 5 ohms. Such a resistance can be purchased.

10th. The antenna current meter A1 should be able to read as much as one ampere and should be either a thermo couple instrument or a hot-wire instrument, calibrated in tenths of an ampere.

11th. The other instrument needed to complete the oscillating circuit is a direct current milliamperemeter A2 that should read up to 200 milliamperes, with calibrations showing every ten milliamperes.

These instruments can first be mounted on a dry pine board and connected up with copper wire, as shown in the diagram of Fig. 52. When the set is finally hooked up, as shown, to an antenna and ground, and a direct or

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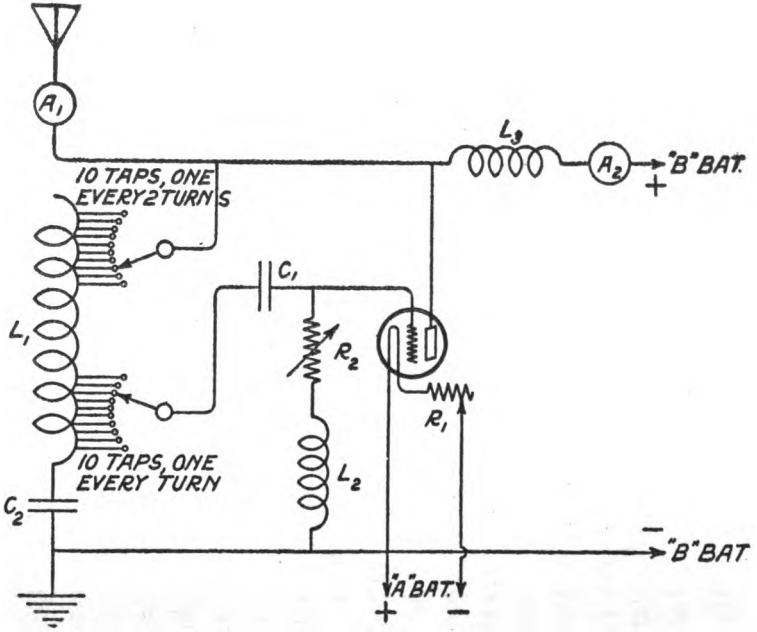

FIG. 52. The oscillating circuit for a vacuum tube transmitter.

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alternating current of about twelve volts, connected to the two wires marked "A" battery positive and negative, and a direct current "B" battery voltage of 350 volts connected across the wires marked "B" battery positive and "B" battery negative and the resistance R1 varied until the current running through the filament is enough to bring it up to sufficient incandescence to support the electron stream across from the filament to the plate, the antenna current meter A1 and the plate circuit meter A2 should begin to read, showing that the circuit is oscillating. By adjusting the bottom set of taps the reading of the plate current meter can be reduced as far as possible without affecting the reading of the antenna current meter. By adjusting the top set of taps the transmitting wavelength may be adjusted, the top taps giving a wavelength of about 350 meters and the lower ones a wavelength of approximately 200 meters with the average antenna.

We now have a set capable of sending out a continuous wave, but we are not able in its present condition to send out any speech. This is where modulation plays such an important

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part. If we connect a microphone transmitter in series with the ground lead and talk into it we will have a method of transmitting speech. If we wish to use the "absorption" method described in the chapter on modulation, we can place a single turn of insulated wire around the inductance L1 and connect the two ends of the wire to the two terminals of the microphone transmitter. Here we have a slight improvement over the first described method.

Then, again, we may try the grid method of modulation, and referring to Fig. 19 we will see that we should connect the secondary of a modulation transformer in the grid circuit of the oscillating tube and connect the primary winding of the same transformer in series with a microphone transmitter and a six volt battery. If we connect a variable condenser across the secondary of the modulation we will find that we can clarify the quality of speech sent out by slowly varying the capacity of the condenser until the speech is the best. The adjustment of the grid tap also plays an important part in the adjustment for clear good speech by the use of this method.

Magnetic modulation may be used and the

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magnetic modulator connected in series with the ground, as will be seen by referring back to Fig. 20.

The most efficient type of modulation to use, however, even though it is more complicated, is constant current modulation. The additional apparatus needed will be the following:

1. One extra vacuum tube, 5-watt.
2. One extra vacuum tube socket.
3. One extra filament rheostat.
4. One extra honeycomb coil, L4.
5. Modulation transformer.
6. 22½-volt grid battery.
7. Microphone transmitter.
8. Constant current coil or plate circuit reactor, as it is sometimes called.

This method makes use of a well-known electrical phenomenon, electromagnetic induction. We have all learned in a general way the function of a transformer, be it inductively coupled or conductively coupled. If a pulsating current is sent through the primary winding, a potential is induced in the secondary winding, but, did we ever suspect that by changing the values of current flowing through a single coil,

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potentials are induced in the coil itself? This is so. An electromagnet resists a current trying to flow through it; that is, it generates a current opposing the voltage impressed on it. When a current *is* flowing in such an electromagnet or coil it tries to keep on flowing, so that if the current is suddenly shut off, it generates a voltage in the *same* direction as the voltage that was impressed, which tends to keep the current flowing. In other words, the electromagnet has a sort of electrical inertia, or momentum, as the case may be, and it is this principle that has been applied to this modulation scheme, and which gives it the name of constant current modulation (see Fig. 53). In this diagram is shown the oscillating circuit, together with the other circuit called the modulation circuit, and the different instruments are shown with a clear view of the connections needed to make the set operate. The oscillating tube draws a certain amount of electrical energy through the constant current coil, and when the voice is impressed on the diaphragm, the modulator tube draws a varying amount of current in accordance with the voice waves. This means that the modulator tube draws its full capacity

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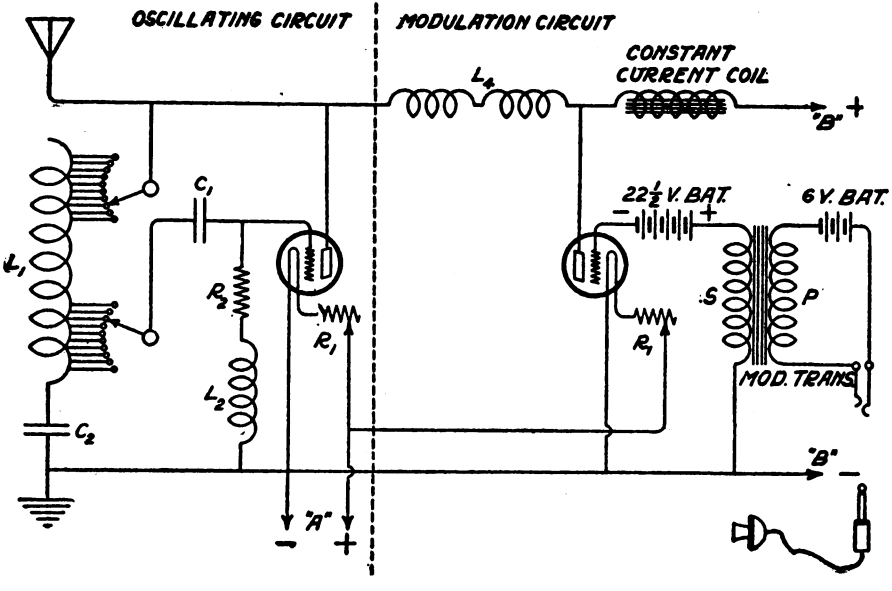

FIG. 53. The constant current modulation scheme connected to the oscillating circuit.

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of current and then when the voice wave falls to a low value the tube draws nothing.

If the action of the constant current coil tends to keep the current which is flowing through it constant it is evident that there must be a varying voltage across the coil. This is exactly what happens, the coil generates voltages, due to sudden changes in its magnetic field, which are alternately in series with or opposed to the voltage being supplied by the "B" batteries. These magnetically generated voltages are shaped into the same low frequency wave that is being impressed on the diaphragm of the microphone transmitter which is connected to the modulator tube through the modulation transformer. In this way the direct current is molded into the shape of the human voice and when this modulated high voltage is used by the oscillator tube to generate sustained high frequency oscillations, these oscillations are also of varying strengths, which are coinciding with the voice wave. By referring back to Fig. 17 we will have our minds refreshed by seeing that this is so.

Tubes of similar power should be used for both oscillator and modulator. The grid of the

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modulator tube should be kept negative by connecting in a 22½-volt battery with the negative terminal connected to the grid. The rest of the circuit explains itself, and when hooked up, as shown in the diagram, all that is necessary is to turn on the tubes and talk. Very few adjustments will have to be made to insure perfect modulation. We have not gone excessively into details in this chapter, only enough to give the amateur experimenter a basis to work from and insure for him a good measure of initial success. Every amateur will soon find out the little kinks and tricks which will get him the best results obtainable with the instruments he has available to work with.

If the apparatus is hooked up, as shown, and suitable "A" and "B" battery supply currents are impressed on the apparatus, according to the size of the tube used, very remarkable results will be obtained. If a number of "B" batteries are used to obtain the 350 volts, or whatever voltage is used on the plates of the tubes, no filter circuit will be necessary. The only trouble with the use of "B" batteries is that they do not last very long, on account of their short life. For this reason most radio

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telephone stations employ a direct current generator driven by a motor. These sets are called motor generator outfits and can be purchased for generating the 350 or more volts used by the telephone transmitter. The only drawback with the motor generator is that while it generates direct current, there are pulsations in the current that would cause a humming sound to be transmitted along with the voice that would interfere with the voice.

This drawback is not a serious one, however, as the pulsations may be smoothed or ironed out by means of the before-mentioned filter circuit. A filter circuit consists of two coils or chokes similar to the constant current coil with iron cores upon which the windings are wound. These coils may be purchased in the supply store and are called filter choke coils. Coils of an inductance of approximately 1½ henries are those most used. One of these coils is connected with each side of the lines coming from the generator to the transmitting set. The function of the coils is to keep the current flowing through them constant, thus smoothing out the pulsations of the generator. Two paper condensers called filter condensers, which have

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a capacity of 1 microfarad each, are connected across the generator to keep the voltage supplied to the set constant. These two sets of instruments in combination keep both the current and the voltage supply to the set constant, so that no fluctuations which would cause a hum can pass. A diagram of the filter circuit

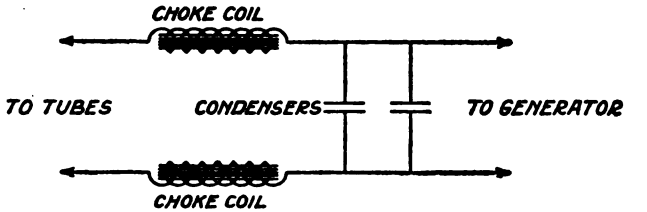

FIG. 54. The filter circuit consists of two coils and two condensers which, when connected as per the diagram, smooth out the ripples of current from the generator, causing a non-pulsating direct current to be supplied to the set.

is shown in Fig. 54. The two output wires marked positive and negative should be connected to the transmitting set in the same way as the "B" battery supply would be connected. The motor generator in combination with the filter circuit thus makes the most reliable and best suited method for obtaining the high voltage supply for a radio telephone transmitter.

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CHAPTER X

SPECIFICATIONS AND INSTRUCTIONS FOR BUILDING A RADIO RECEIVER

THERE are a number of different types of radio receivers that would interest the beginner in radio, but there are only three types that should interest the radio broadcast listener. The first is the simplest set that it is possible to build, the single slide tuner and the crystal detector for receiving distances up to fifty miles. The second type of set is the audion type of set with an inductively coupled tuner for receiving ranges up to 100 miles. The third type is one using the inductively coupled, regenerative audion circuit, with two steps of audio frequency amplification. This last type will receive with a good antenna from distances up to several hundred miles, and can be used with a loud speaker.

The first type of set is very easily constructed and will give fair results where the receiving station is located near the broadcasting station.

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The one great advantage of such a simple receiver is that it requires no batteries, and the only operating expense is that it requires new crystals from time to time.

The first instrument to build will be the single slide tuning coil, although this can be purchased

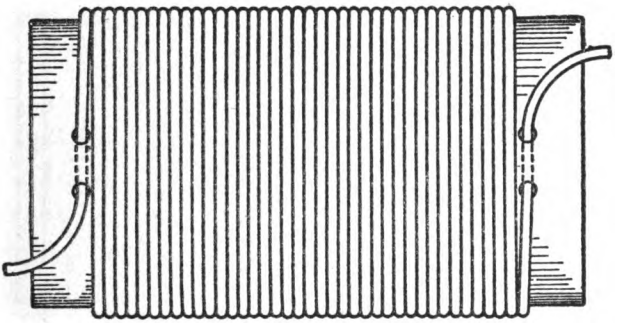

FIG. 55. The method of winding a coil, showing how to fasten the ends of the wires.

for a small sum if desired. Obtain a cardboard, fiber, or bakelite (preferably bakelite) tube six inches long and three inches in diameter. Then on this tube wind on No. 18 solid copper enamel-covered wire, starting one-half inch from one end of the tube and finishing one-half inch from the other end. The method of starting and finishing the coil is shown in Fig. 55.

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This is done by boring two holes through which the wire is threaded before and after starting and finishing the winding. The winding is finally held firmly by applying a small quantity of sealing wax to the inside of the coil at the

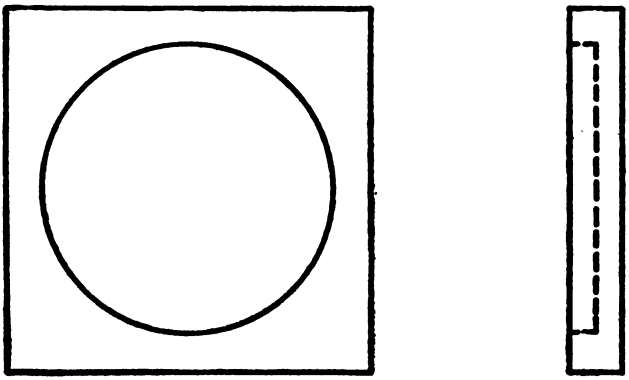

FIG. 56. End supports for the coil. There are two needed for every coil. They can be made of dry wood, with a circular section cut out of one side to hold the coil tube.

spots where the wires are brought through the holes in the tubes.

The next job to think about is the slider for the coil just made. First, we will have to make a couple of wooden supports for the coil, and

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these should be made of dry wood, in the shape shown in Fig. 56.

After these are fastened to the ends of the

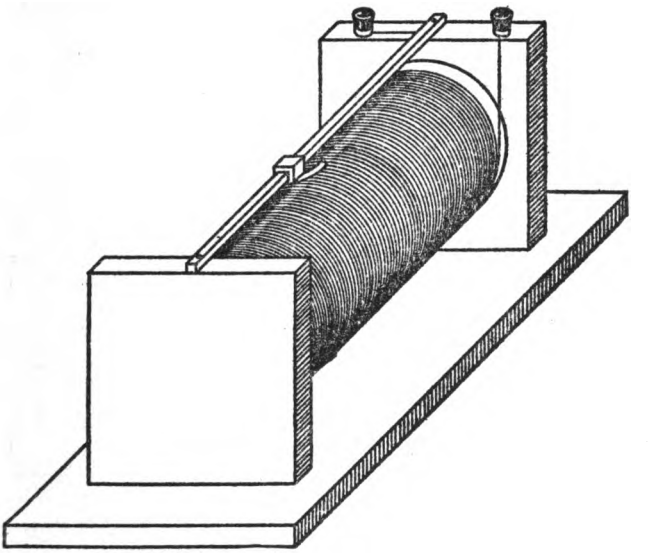

FIG. 57. Picture of completed coil showing slider and connecting posts. One post is connected to the end of the coil and the other to the slider rod. By running the slider back and forth, tuning is accomplished.

coil a piece of brass rod about one-quarter of an inch square should be connected across between the wooden end supports. This rod

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will be used for the runner of the slider. The slider proper is made of a rectangular piece of brass with a square hole cut through it so that it will slide back and forth on the rod smoothly. An insulated knob can be attached to the upper side of the slider and a phosphor bronze strip attached to the lower side of the slider by two small screws. This strip will be used for the contact making device which slides over the wires, and picks out the particular wavelength it is desired to "listen in" on. The wires should be scraped bare where the slider is to run. A picture sketch of the completed coil with the two binding post terminals is shown in Fig. 57.

Then a crystal detector and a pair of telephones should be obtained, with a small "phone condenser," which is connected across the telephones, and all the instruments should be connected up, as shown in the Fig. 58. The only adjustments necessary with this type of receiving set are to adjust the crystal detector to sensitiveness, and move the slider up and down along the coil until the desired signals are picked up.

The second type of receiver is the one using

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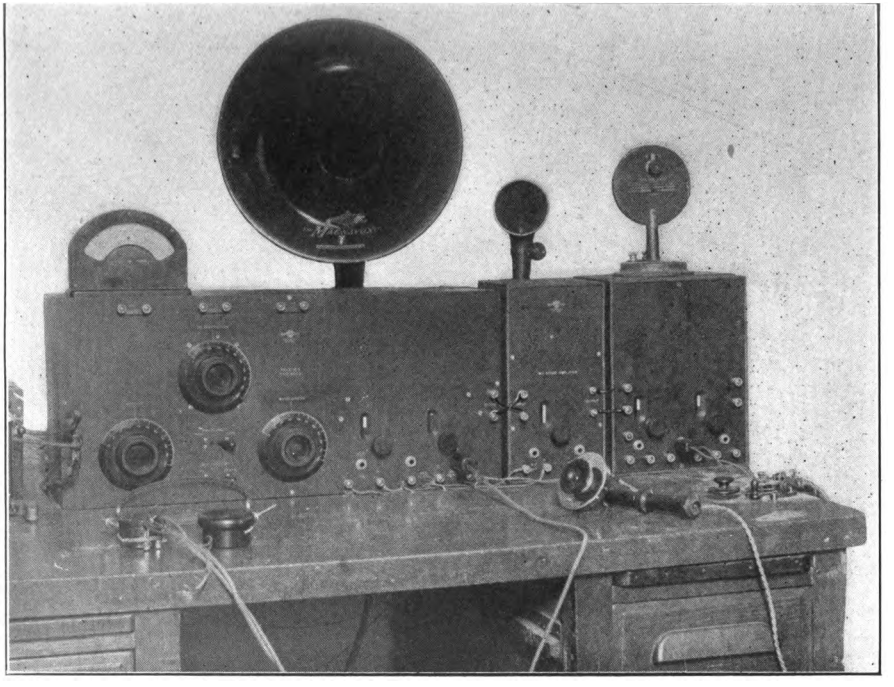

A receiving set with numerous stages of amplification. This set is similar to the third set described in the following chapter. Notice the loudspeaker horn. When a set of this type is connected to a loop antenna, music and speech can be tuned in so that they can be heard great distances from the horn. This particular set has been heard more than a quarter of a mile away when the horn has been placed facing an open window.

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the inductively coupled tuner or loose coupler as it is more generally known, used in combination with a vacuum tube detector.

It will be better to buy the different instruments than to try to make them at home and

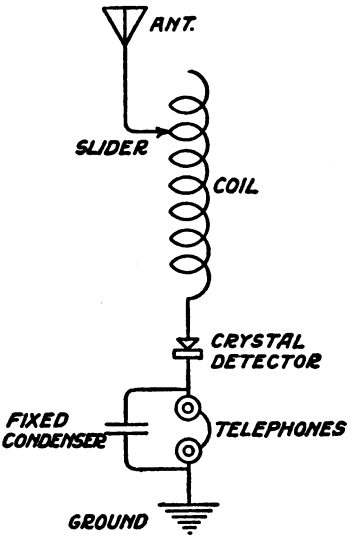

FIG. 58. Circuit using a one-slide tuning coil and crystal detector for receiving.

the results will be superior. Obtain one loose coupler of the wavelength that you wish to listen on, a pair of telephones of 2000 to 3000

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ohms resistance, one vacuum tube detector tube, one filament rheostat of 5 ohms resistance, one vacuum tube socket, one grid condenser of .0005 microfarads capacity, one grid leak of

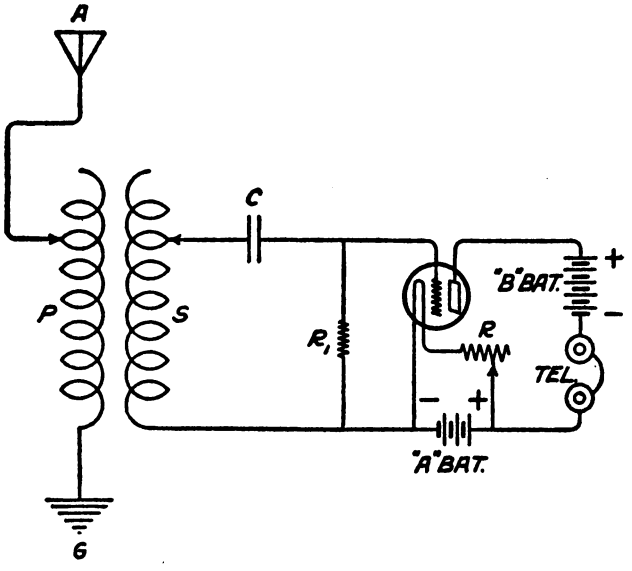

FIG. 59. Circuit using a loose coupler and vacuum tube for receiving.

2,000,000 ohms resistance, one six volt storage battery of 40 to 60 ampere hours capacity, and a 22½ volt "B" battery. All of this apparatus

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may be purchased from regular radio stores which have a sign outside the window bearing the word Radio. The salesman will know what you want if you mention the instruments as indicated above. Then you can take them home and hook them up with suitable connecting wire as indicated in Fig. 59. The adjustments necessary with this set are the adjustment of the filament resistance, the coupling, and the wavelengths of the primary and secondary coils. This set will be found to be much more sensitive than the set first described and also will be much more selective, that is it will be able to tune out interfering stations more readily than the simpler set. It will be possible with this set to add an amplifier so that the signals may be heard with a loudspeaker.

Note: The third set to be described is composed of the following instruments. The instruments here listed should enable the man who assembles them and uses them to hear on all wavelengths between 180 meters and 800 meters:

One variocoupler, of a reliable make.

Two variometers (those employing no shellac on the windings are preferable).

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One grid condenser (same as used in preceding set).

One grid leak (same as used in preceding set).

One vacuum tube (detector).

Two vacuum tubes (amplifiers).

Three vacuum tube sockets.

Three filament rheostats.

Two audio frequency amplifying transformers.

One pair of head telephones.

One magnavox loudspeaker.

One six volt storage battery 80 ampere hours capacity.

Three 22½-volt "B" batteries.

Necessary binding posts, taps, and one switch arm and knob, connecting wire, etc.

After the above instruments have been procured, connect them up as the diagram in Fig. 60 plainly shows and turn on the tubes and listen. The tuning and adjustment of this set are a little more complicated than the two preceding sets, but the results are far in advance as far as loudness of signals and selectivity of tuning are concerned, and the set will receive from much greater distances under the same

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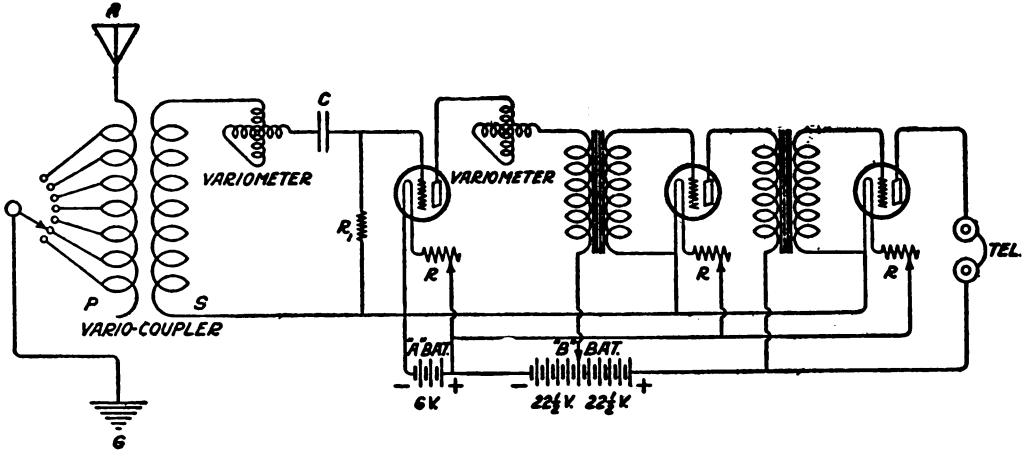

FIG. 60. Regenerative receiver with two stages of audio frequency amplification attached to increase the strength of incoming signals to great volume.

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conditions. The two variometers are placed in non-inductive relation (windings opposing) and the variocoupler coils placed so that their fields are both in the same direction and both occupy the same space, or in other words are closely coupled. The filaments are then turned on by adjusting the rheostats to the correct value so that a rushing noise is heard in the receivers. The amplifiers are now in working order if this sound is heard. An occasional crackling of static may be heard.

The next move is to adjust or vary the wavelength of the primary circuit for either a high or low wavelength whichever it is desired to receive on. This is done by cutting in or out a number of turns in the primary circuit by means of wavelength switch and the taps on the coil. If a large number of turns are left connected in the circuit, higher wavelengths will be heard loudest. If fewer turns are connected into the circuit a correspondingly lower wavelength signal will be tuned in loudest. When the primary circuit is tuned in roughly in this manner, the secondary is adjusted to the incoming wavelength by means of rotating the knob of the grid variometer back and forth till the desired

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signal is audible in the telephones. Then the plate circuit is adjusted by turning the knob of the plate circuit variometer so that the signals may be increased in strength. If this variometer is turned too far however, the signals will be distorted and the variometer should be turned back to the setting where the signals are loudest without distortion. If the signals should be blotted out due to interference from some nearby station the proper procedure to follow is to loosen the coupling between the coils of the variocoupler until the signals are very weak. Then by returning all the controls, the signals may be brought back to the proper strength without also bringing up the strength of the interfering station. The tuner tunes much sharper with loose coupling than with close coupling. In this way this type of set cuts out trouble to a large extent that is due to interference or what is known in the international radio abbreviation scheme as QRM.

The loudspeaker is connected in parallel with the phones so that the operator may tune in the signals while the listeners may at the same time enjoy the music or speech that is being tuned in. When a broadcasting station is

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finally tuned in as good as it can possibly be gotten, it is usually a good thing to disconnect the telephones leaving the loudspeaker working by itself. The signal strength will be slightly increased if this is done.

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CHAPTER XI

CARE AND MAINTENANCE OF APPARATUS; HINTS

IN the opinion of the author this will be the most important chapter of this little book. In it we will try to give some information of practical helpfulness to those who are beginning to find interest in this fascinating game of radio. We believe that the man who has honestly read the preceding chapters will have a working understanding of the subject so that whether he decides to assemble a receiving set or to buy one complete, he will know enough about the working of the apparatus, and the functions of each part and understand in general the adjustments necessary for tuning so that he will get a whole lot of enjoyment and educational value out of his proposed radio set. But we wish to add this practical information which will be more specific in order that he may know how to keep his apparatus in condition.

After all radio apparatus is very delicate

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apparatus, for instance, take the vacuum tube: the filament can be broken by a jar such as laying the set down too hard on the table. Variable condensers, variometers, variocouplers and other rotating instruments must be "handled with care" so that the shafts and bearings upon which they turn are not bent or injured. The flexible connections which conduct the currents through the movable parts must be watched to see that they do not break apart. Sometimes the rotating plates of the variable condensers shortcircuit by warping which causes them to scrape on the stationary plates when rotated. These and numerable other kinks to remember which are liable to happen and make life miserable to the beginner before he finds out what the trouble is, we will now set forth in the hope that they may help some "poor amateur" who has that particular trouble.

The author has had many of the same kind of experiences himself and only recently spent the larger part of one whole evening chasing that elusive phantom—Trouble in the Receiver—during which time he fumed and perspired and pulled apart the wiring of the set,

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connected it up again, tested it out again, fumed some more, pulled it apart again, and so on, all on account of listening to a large broadcasting station sending out music. The author and some friends were listening to the very enjoyable program which was being sent out by this very reliable broadcasting station (remember, that friends or guests must always be present when the set "goes wrong"). Well, we were having a fine time listening to the music which was being received very loudly and clearly on a fairly good set with a loudspeaker, when suddenly the music abruptly faded out to a very weak condition as if the broadcasting station had suddenly jumped a thousand miles or so away. I looked at the friends and then at the set, and they looked at the set and then at me, with a look of expectation. I was puzzled. Just as suddenly the music crashed in at full strength again and the friends and I again exchanged glances and smiles were on their faces and I have no doubt that relief was registered on mine. Wait a minute, I began to think. Signals fading in and out? Ah—my antenna must be touching periodically, thus causing it to partially short circuit to ground.

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So I excused myself and got a flash lamp and hied myself up to the roof to "look at the antenna." Everything was found to be in good order on the roof and the lead in wire was not touching, so the trouble, thought I, must be in the set. Downstairs again as fast as my legs would carry me, where the friends laughingly told me "it did it again" a couple of times, and "it made funny noises," and "it sounded like the wind blowing" and I confess this good natured joshing got me all fussed up, as radio through long association had become a part of myself, and such remarks hurt me almost as much as a slap in the face. So I decided to find out the trouble, remedy it, and "show them" that I was the master of the set. I excused myself again and taking off my coat and rolling up my sleeves I began tearing apart the set, and testing out the continuity of each circuit with a battery and telephones, testing every flexible connection, the contacts on the tube sockets, connections to the "A" battery and the "B" batteries and so on, until after a hurried search without finding anything wrong I again reconnected up the set to the antenna and ground and began to tune in for the music.

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After a few seconds it roared in fine and clear. Everybody was beginning to comment how simple the thing was when you knew the function of the instruments and how to fix them, referring to the easy way I had repaired the set, and I rolled down my sleeves and put on my coat and sat back feeling much better. "What was the trouble?" I was asked. I replied, "I guess there was a loose connection somewhere," though I did not really see where the trouble had been as yet. "Well it is working fine now," said one, and the words were hardly out of his mouth when—out went the signals once more—with the accompanying pained expression on the faces of the guests. Said I, "I am going to fix that thing once for all," and accordingly I began to go over the testing and tracing out of the circuits once more, only this time more thoroughly. After assuring myself that everything was O. K. I again reconnected up and found that the same conditions were repeated. Then I knew that it was not my set and I had worked and fussed over the thing for quite a long period of time and was plain angry. I felt sure it was not the set so to satisfy myself I tuned in a couple of

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amateurs who were talking together with each other over their small radiophones and they came in fine without any fading or any other trouble whatsoever. I was not paying any particular attention to their conversation, but was just tuning them in so that my friends could hear both sides of the conversations, via the loudspeaker, when I heard one of them say, "Hello 2BNL, say what was the trouble with WJZ to-night? He came in with jumps and starts, fading in and out, and I tore down my set looking for the loose connection, two or three times, until I found out that the trouble was at WJZ." "WJZ" are the call letters assigned to the particular broadcasting we had been listening to. 2BNL replied, "Hello 2CAK, say, George, I did the same thing, but I didn't like to speak about it because I was so sore at myself when I found out the trouble. Wouldn't that make you mad?"

At this point my friends in the house began to laugh and I had to admit the joke was on me. I broke into the radio conversation between 2BNL and 2CAK, having a more powerful transmitting set than they and told them both in a very amusing three cornered radio "chat"

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that I also had been duped into tearing apart my set looking for the trouble when it was caused by the breaking down of the station WJZ. (We later found out that WJZ's antenna had been grounding periodically against a steel tower on account of the high winds.) We heard these two amateurs talking later and one said to the other, "Well I guess it isn't so bad that we thought it was our set, when 2XK made the same mistake." We heard them laughing at the joke on me.

Let us first take up a few minutes with consideration of the antenna. The antenna must be well insulated and this is usually done by stringing the wire or wires between insulators which are made for the purpose and can be obtained at any radio shop for a small sum. The wire must not touch any trees, stone walls, or any other foreign objects. It should be kept as far away from these objects as possible, at least ten feet, for efficient results. It should not be strung in an alley where it will be obstructed by high buildings or the like. For receiving, one wire 100 to 150 feet in length will be the simplest and best. This wire can be stretched horizontally with the ground, with the

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lead in taken off at one end. Refer to the chapter on antennae and the Inverted L antenna in particular. All joints should be soldered. Almost any wire larger than No. 18 can be used and it doesn't make much difference whether the wire is insulated or not.

Do not run your antenna across the street as you will be violating a city ordinance and make yourself subject to a fine.

Do not try to receive during a thunderstorm. Ground your antenna and sit back safe in the knowledge that a grounded antenna affords the best kind of lightning protection it is possible to obtain. The safest way to ground your set is to obtain a single pole, double throw switch and connect the blade to the antenna lead in and one pole of the switch to the instruments and the other pole to an outside ground wire that is run as directly as possible to a pipe, one end of which is extended several feet into the ground. The ground wire should be a No. 4 bare copper wire, to fulfill the requirements of the National Board of Fire Underwriters. A diagram picture is shown in Fig. 61. When the set is not in use the switch blade should always be thrown to the ground pole which

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disconnects the instruments from the antenna and connects the antenna directly with the ground, thus leading any high voltages that

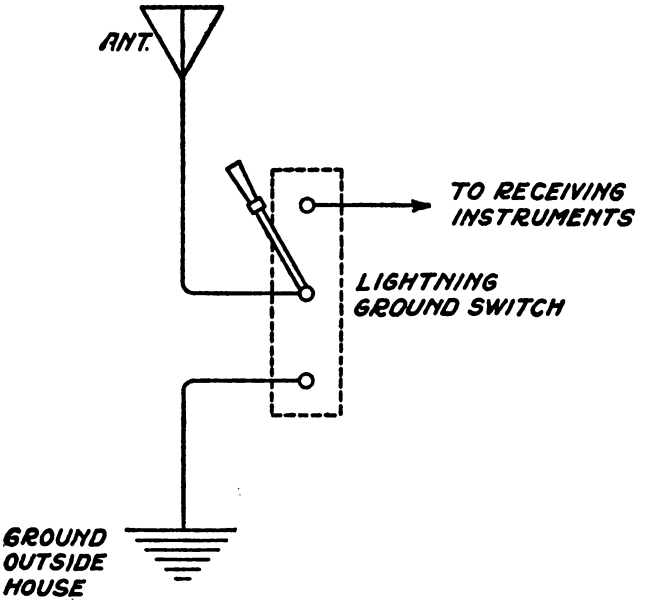

FIG. 61. Lightning protective switch and method of connecting to an antenna and instruments.

may accumulate on the antenna due to lightning flashes, to the ground outside of the house. This will afford you ample protection and leave the women folks of your family without any

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basis for argument on the subject. It should also set their minds at rest as far as personal danger is concerned. The insurance on the house will also be protected if the lightning switch is properly installed. These are good reasons for putting in the lightning ground protection.

The lead in wire should not be run long distances through the house as the electrical capacity between the wire and the walls or ceiling will have an absorbing effect which will cut down the strength of the received signals.

One of the first problems that confronts the amateur who builds most of his set, is the construction of his inductances or coils. When he comes to this stage of the game he should bear the following pointers in mind:

He should use a material for the tube (on which the wire is to be wound), which will not absorb moisture; cardboard is not good for such use for this reason. Some amateurs coat the tube with shellac or varnish or sometimes impregnate the tube with melted paraffin to make it waterproof; this removes the trouble from electrical leakage due to the presence of moisture, but it has the disadvantage of increas-

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ing the distributed capacity of the coil, which makes the set (of which the coil is a part), "tune" broadly.

The best type of material to use is known as Bakelite, Formica, Condensite, Celeron, and various other names. These substances are built up from a number of sheets of high-grade paper which have been vacuum dried and then impregnated with a synthetic resin; they are then subjected to a heating process and at the same time molded into the desired shapes at tremendous pressure.

The wire should be wound on the tube and fastened tight by applying seals of sealing wax to the ends of the wires. This holds the winding in place without any shellac or paraffin, which is so dangerous to tuning efficiency.

The best kind of wire to use for this purpose is a copper wire with a silken covering.

When actually mounting the coils keep all magnetic materials, such as iron screws and iron brackets, as far away from the coils as possible, as these materials will choke back the extremely weak high-frequency currents which have been received and are trying to pass through the coils.

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Another point to remember in connection with coils is to have all coil ends joined on the rest of the wiring tightly and then soldered. This is true of all joints between wires in the set, and brings up the matter of soldering to our attention.

There are four points to be remembered when making up a soldered joint; first, the surfaces of the parts that are to be joined should be cleaned and polished; second, the surfaces should be treated with a soldering flux; third, the temperature of the soldering iron should be kept at the right heat; fourth, the metal parts should be heated with the hot iron and just enough solder applied to cover the parts neatly.

If these precautions are taken every joint will be a real joint, and the apparatus thus connected up will function in a quiet, clear manner, without any of the hissing, or crackling sounds that invariably accompany an improperly connected set.

All metal parts to be joined should be rubbed and polished to a bright, shiny finish, with emery cloth. All coverings such as lacquer,

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grease or oxidation should be removed from the surface of the metal.

The purpose of using the soldering flux is to cause the molecules of molten solder to amalgamate with the molecules of metal to which they are applied. There are a number of fluxes, the chemical constituents of which cause this action to take place. The soldering paste may be applied with a small stick. Use only enough to cover the surfaces with a thin film, however; excessive use of paste causes a dirty joint and this sometimes means trouble from leakage.

A small one half pound iron (which by the way is made of copper) should be used. To prepare the iron, clean the point with a smooth file, or emery paper to a distance of about one half inch from the point, and then place the iron in a clear gas flame and heat it until a green tint is seen in the flame around the iron. Then apply soldering flux to the point and rub a piece of solder over the cleaned point until it is covered with a thin covering of solder. Then place the iron back in the flame but keep the point out of the flame. The iron should never be heated beyond the temperature at which the solder begins to turn a dull gray.

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Remember that if the iron gets too hot, it will oxidize and the solder will not stick to it, and it will have to be cleaned and tinned all over again. Of course the electric iron is preferable, because the possibility of overheating is forestalled, as the iron is designed to work at the correct temperature only.

When the iron is at the correct temperature, place the point of it on the surfaces of the wires to be joined, and heat them for a moment while the flux bubbles up; then place the end of the strip of solder on the parts until enough solder melts and flows over the surfaces to make a neat joint. Do not use any more solder than absolutely necessary. Work the molten solder around with the point of the iron, until every crevice is filled, and then take the iron away, and refrain from moving or disturbing the joint until the solder "freezes" or sets. Wipe off the excess soldering paste, and the job is complete. The handiest kind of solder to use is a soft solder put up in the form of a wire about one eighth of an inch in diameter. After a few trials the process becomes simple, provided these precautions are taken. And the results obtained from the completed instrument will

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be well worth the effort made to do a good soldering job.

When wiring up your set do not make all the wires run in nice straight lines, with nice sharp corners at right angles, but do the wiring with the shortest lengths of wires possible, running the wires in "Bee" lines. This will insure the highest efficiency as every extra foot of wire adds resistance to the circuits that waste energy that could be used for conversion into sound.

Do not run any wires parallel for any distances in your set as they will act as a condenser and the high frequency currents passing them may be used up in charging these imaginary condensers and will never find their way to the phones. In other instances running wires parallel may cause the set to tune improperly or it may cause it to emit howling sounds, that spoil any incoming signals or music and speech.

It is a standard practice to cover connecting wires inside the set with an insulating tubing called varnished cambric tubing. This is slipped over the wire when the length of the wire is determined and then the wire is fastened and soldered. In this way the wires and cir-

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cuits are protected from each other and no short circuits are liable to occur, such as running down the batteries or destroying the vacuum tubes.

When selecting a panel for your proposed radio set, choose a material that will not absorb moisture. Wood may be treated by immersion in a bath of melted paraffin which is being heated. The wood should be left to soak in the heated bath until all bubbling ceases. These bubbles that will be observed coming out of the wood are gases and moisture. The temperature should be kept at about 100 degrees Centrigrade, which is the boiling point of water and which causes the water to leave the wood in the form of a gas or steam. When the bubbling ceases, take out the wood and hang it up to dry and cool. It is then moisture proof and ready for use. Of course the apparatus will have a more commercial look if the panel is made of bakelite and it also will be moisture proof as bakelite possesses this quality without any treatment.

When mounting the instruments behind the panel first consider how the connections are to run and arrange their positions in respect to

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each other so that they will be readily connected without the use of exceptionally long lead wires.

Also try to arrange the instruments so that the controls that will be the most used, the tuning controls, will be at the bottom of the panel so that the arms will not become tired when tuning the set over a continued period of time.

Too much stress cannot be laid on the importance of careful and painstaking planning and forethought, before actually starting on either the purchasing, or the assembling of a radio set whether it be for transmitting or receiving.

Regarding mounting the instruments; the crystal detector should be placed in a convenient position on the set so that the operator does not have to go through any process of gymnastics in getting it adjusted. The resistances for controlling the filament current of vacuum tubes should be placed on the panel close to the tube socket so that long leads will be eliminated. The tube sockets themselves should be mounted so that the filaments in the tubes will be suspended vertically so that they will not sag when heated by the current passing

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through them. If the filaments sag they may sag enough to touch the grid and thus make the tube useless. Mount the tubes vertically.

If amplifying transformers are mounted close together in a set, place them at right angles to each other so that the magnetic fields of each will not be in the same direction. This will prevent magnetic coupling between the different stages. If this precaution were not taken the amplifying circuit would most undoubtedly "howl" or make queer squeaking noises.

When building transmitting sets always keep in mind the necessity of separating the high frequency circuits from the low frequency circuits as if this is not done the low frequency circuits will absorb energy from the high frequency circuits and the set will not be efficient. That is, the energy lost from the high frequency circuits will do no good as far as transmitting is concerned because it will never get to the antenna.

Do not crowd the instruments together to make the set compact. This is sometimes the only thing that prevents a beginner's set from functioning properly, the instruments are

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crowded together so close that they interfere with the working of each other. This interference we are speaking about of course is an electrical interference and not a mechanical one.

Arrange the binding posts on the panel so that they will best suit the circuit used in the set. Make them convenient for connecting to the "A" and "B" batteries without having the connecting wires sprawling all over the panel. These wires should be out of the way of the operator's hands while tuning, as the capacity of the hand to the wires may throw out the tuning of the set.

If the set uses a storage battery, get a good one of standard make. It does not pay to obtain a cheap storage battery, because if it is cheap you may depend it is not of such a good quality and will cause you trouble in the long run. The best storage battery is the best battery and in spite of the higher initial cost you will make it up in a short time in satisfaction whereas if you get a cheap one you more than probably will be sorry in a few months.

We will now go into details of the care and maintenance of the storage battery which is

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usually called the "A" battery in radio terminology.

The "A" batteries used for lighting the filaments of vacuum tubes used in radio work usually comprise several cells mounted in a wooden or hard rubber case. Each cell has two lead plates in the form of a grid, one of which is known as the positive plate, marked (+), and is pasted over with red lead (which becomes lead peroxide), and the other plate, known as the negative plate, is marked (—) and is pasted over with litharge (which becomes spongy lead). These pairs of plates are immersed in separate jars filled with a solution of water and sulphuric acid. The positive plates are separated from the negative plates by porous insulating material, and the cells connected in series, the end cells having connecting posts marked positive (+) and negative (—). Each cell will read 2 volts normally, or in the case of the common 3 cell battery, the voltage read at the connecting terminals would then be 6. When a battery is freshly charged, the voltage will be slightly over 2 volts per cell, and when discharged to the safe limit, each cell will read about 1.8 volts. Another way to determine the

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state of charge or discharge of a battery, is to take a hydrometer reading. The vent cap of each cell is removed, and by means of the hydrometer syringe (see Fig. 62), enough of

FIG. 62. The hydrometer syringe for determining electrical condition of the storage battery.

the battery liquid, called electrolyte, is drawn up into the glass tube to float the hydrometer. When pressure of the hand on the rubber bulb is released, the hydrometer will come to rest, floating upright, and not touching the walls of

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the glass tube. The point on the hydrometer scale which coincides with the surface of the liquid, indicates the correct reading, which should be about 1.275 or 1.30 when cells are fully charged, and about 1.125 or 1.150 when discharged, this figure representing the specific gravity of the electrolyte.

Usually, when the battery is first received, it is fully charged, but in some cases, it is necessary for the purchaser to mix the electrolyte, fill the cells, and give the battery its first charge. The sulphuric acid should be poured into an earthenware jar, which has previously been half filled with distilled water. Caution:—Never pour the water into the acid, but pour the acid slowly into the water, being careful to stir with a glass rod. Sufficient acid should be added to obtain a hydrometer reading of 1.20 to 1.24 Sp. Gr. None but the sulphur or brimstone acid should be used, and both the acid and water should be free from impurities. When cool, this solution is ready to be poured into the cells, to a point at least ½ inch above the plates. From time to time, it will be necessary to add distilled water to replace that lost by evaporation, but, as the acid does not evaporate,

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none should be added to bring up the specific gravity (hydrometer reading). The correct way to raise a low reading is to properly charge the battery, unless electrolyte has been lost by spilling or other accident.

Charging: Where only alternating current is available for charging, either a magnetic vibrating charging unit may be used, or a tungar rectifier unit. The former consists of a small step down transformer, and a vibrator operated by an electro-magnet in such a manner that the circuit is completed to the battery only when the alternating current impulses are flowing in the proper direction. The latter device consists of a small step down transformer and a special form of two element vacuum tube, which passes to the storage battery, only the impulses which flow in the proper direction. Both of these devices are manufactured in convenient portable form, and may be obtained from any good electrical or radio dealer. Care must be taken with either of the foregoing charging units, to connect the terminal of the charging unit marked (+) to the terminal of the battery marked (+), and (—) to (—).

Where direct current is available, a bank of

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six 100 Watt (32 candle power) carbon lamps may be connected to the 110 volt line in parallel, and the storage battery in series with these, as shown in Fig. 63.

The charge should be continued until it is certain that the battery is fully charged. Near

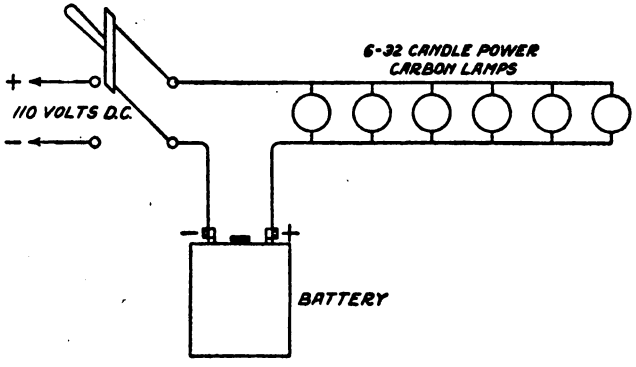

FIG. 63. Charging storage battery with direct current through a bank of lamps.

the end of the charging period, the cells will "gas" freely, and the precaution should be taken to open the vents of each cell during charging. When the cells are fully charged, the "gassing" effect will show a marked increase. The voltage and the specific gravity

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will reach a maximum value (which is seldom exactly the same for any two batteries), but this maximum value will remain constant until the charging current is cut off, if the battery is "full." The maximum voltage per cell reached when battery is fully charged may be from 2.4 to 2.7, according to the individual battery. As the age of a battery advances, the maximum voltage at the end of the charge will decrease slightly.

Care should be taken to keep the top of the battery free from moisture, which may gather during charge from the gassing, or from replacing water from time to time, and unless this moisture is wiped off, "creeping" will begin, which means that through electro-chemical action, the current leaks across the battery top, not only eating away the terminals, but discharging the battery slowly. It is a good plan to cover all exposed parts and surfaces with a thin coat of vaseline occasionally.

Note: If battery electrolyte should be spilled on the clothing, carpet, or any fabric, or on wood flooring, ammonia should be quickly applied to all parts so affected, otherwise the acid will eat holes into such materials in short

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time. Batteries should be set in a shallow tray of sand, or on a square of thick rubber mat.

The "B" batteries are made up of a number of small flashlight dry battery cells all connected in series, and contained in a rectangular shaped box, and the cells sealed in with an insulating compound. In some "B" batteries only two leads are brought out, one the positive lead and the other the negative lead. The positive lead is usually covered with a brightly colored cloth braid, and the negative lead covered with a black cloth braid. However, if there is any doubt in your mind which is the positive lead for connection to the plates of the tubes, you may test out the battery by the following method and make sure. Take the two leads from the battery and immerse them in a cup of water to which has been added a teaspoonful of salt. Do not let them touch of course as this would short circuit the battery and end its usefulness, as such batteries have a very low current capacity. After the leads of the battery have been under water for a short length of time, it will be noticed that one of them becomes covered with a whole lot of little bubbles. This lead wire is the negative,

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and the other one is the positive. This will hold true for any kind of a battery.

"B" batteries usually are put up in blocks as stated above and the voltage of these blocks is 22½ volts per block. This type of battery consists of 15 cells of 1.5 volts per cell. Some batteries are tapped from the eleventh cell to the fifteenth cell so that by attaching to any particular tap, the operator can use any voltage on the plate of his detector tube that he finds best suited to it from 16.5 volts to 22½ volts. Detector tubes are generally very critical as regards voltage supplied to the plate and this type of battery is more efficient for this class of tube. Amplifier tubes are pumped to a much higher vacuum and will stand a much higher voltage without ionizing, in fact amplifier tubes work better with voltage in excess of 22½ volts on the plate and the increase of response of the tube is increased as the plate voltage is increased. It is not advisable, however, to put more than 125 volts on these tubes. The usual practice is to connect a 22½ volt tapped "B" battery to the detector tube and four additional 22½ volt untapped "B" batteries in series on the plates of the amplifiers. With this arrange-

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ment of "B" batteries very good results can be obtained with the use of the loudspeaker. In other words a loudspeaker will work much better if the amplifier tubes have a rather high voltage applied to them than if the single 22½ volt battery alone were used. This is because the additional voltage makes the plates of the amplifier tubes more positive and this attracts the electrons at a much greater rate over from the filament to the plates. This in turn results in a much greater plate current thus causing more current to flow in through the loudspeaker with a correspondingly greater volume of sound emitted from the loudspeaker. The loudspeaker is connected in series with the plate circuit, in the same way as the telephones would be connected.

When tuning in signals, especially speech or music, do not make the mistake of trying to get the signals in the loudest possible. This is the most frequent fault of the radio fan, and it really spoils the fun for the rest of the listeners. The regular radio fan's greatest achievement, in his own mind, is in getting the signals the loudest possible. He does not pay any attention to what is being said or sung or

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played by the broadcasting station, but his every effort is directed toward getting the loudest signals. He tunes in the music so loud that it sounds like a mixture of a storm and a railroad train passing by to the accompaniment of a few roosters crowing and a thousand fife and drum corps all going at the same time. And then the listener who has never heard the radio before says, "Well I admit it is a wonderful thing to think that you can get anything at all out of the air, but give me my Victrola."

This is all wrong because the music sent out via radio can be reproduced with all the clarity of the original spoken word; or the notes of the flute or whatever music is being transmitted can be reproduced with true and faithful rendition so that the repeated sounds will hardly be distinguished from the original.

So do not make this great mistake and take all the fun out of receiving, especially if you have a regenerative set; as the regenerative set, though it is a wonder for amplifying and bringing in loud signals, is the worst offender when it comes to distorting signals, if the operator does not guard against the temptation of tuning in the signal too loud.

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Be sure to handle your vacuum tubes with care or you will regret it. The filament of the tubes are the same as the filaments of the electric light that you use in your home to give out light. If you bounce one of them on the table you will be likely to damage the filament, break it, in other words, and you will be "out" the price of a tube.

The same applies to the telephones. Handle them with care. The telephones contain a permanent magnet that will be affected by any sudden shocks. A permanent magnet loses its magnetism upon being struck a sharp blow, such as being dropped on the floor. This decreases the sensitiveness of the telephones and every time they are banged around they lose a certain amount of their original sensitivity.

Hang the telephones on a small hook when not in use so that they will not be dropped on the floor and be careful with them when they are in use. With careful usage the telephones should last indefinitely without any appreciative loss in sensitivity.

A good way to test out an amplifying transformer to find out if it is open-circuited, is to connect one end of the winding to one terminal

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of the head telephones. Then with the telephones on the ears touch the other terminal to a dry cell which is connected to the other end of the winding of the transformer. If the transformer winding is O. K. there will be a clicking noise heard in the telephones. Then try the same thing with the secondary winding of the transformer. If no clicks are heard, one of the windings of the transformer is "open." A circuit for making this test is shown in Fig. 64.

The sensitivity of an audion tube may sometimes be increased by placing a large horse-shoe magnet in a certain position so that the poles of the magnet are on each side of the tube. This probably is due to the magnetic effect upon the moving electrons flowing across from the filament to the plate. The amateur experimenter will find this a good field for him to investigate as he may hit upon some new idea along this line that will be an improvement upon the present day vacuum tube. Needless to say, if this should be the case, his fortune would be made.

A wavemeter is a device for measuring the wavelength of either a signal which is being

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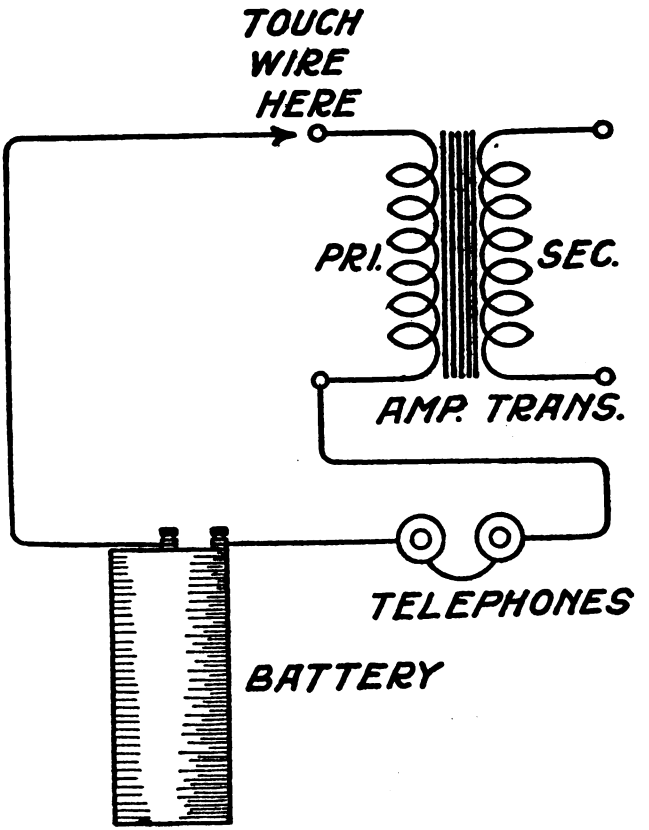

FIG. 64. Method of testing the windings of an amplifying transformer.

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transmitted from a station or which is being received at the station where it is in use. It consists essentially of an inductance or coil (or a number of coils for different wavelength ranges) across which is connected a variable condenser. When the variable condenser is rotated the capacity of the condenser changes, thus varying the frequency that the circuit will respond to. If we know the frequency that the different settings of the condenser correspond to, we can easily find out the wavelength that corresponds to that frequency from a table of frequency and wavelength.

Most wavemeters have a switch which enable the wavemeter to be used for determining the wavelength of either a transmitted or a received signal.

The first mentioned use is for tuning a transmitting set and the second use is for finding out the wavelength of another station which is sending at the time. A diagram of connections is shown in Fig. 65 for such a wavemeter.

When the switch is thrown for determining the wavelength of the transmitting apparatus in the station, the wavemeter is really in effect a small receiving set without any antenna cir-

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cuit. A crystal detector is used and when the wavemeter is placed somewhere near the coils of the transmitter, the wavemeter may be tuned by rotating the variable condenser till the signal is heard loudest in the telephones. When this

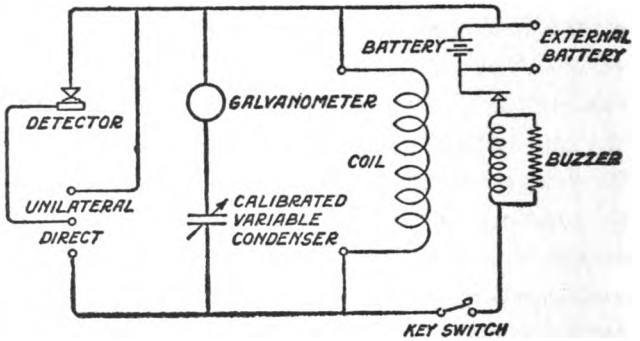

FIG. 65. Circuit wiring of a wavemeter for determining wavelength of radio waves.

is done, the wavemeter has been tuned to the same wavelength as the transmitter and this wavelength may be read directly off the calibrated scale of the variable condenser, which is calibrated in meters. In this way the operator may be sure that he is sending out signals of a wavelength that is lawful for him to use.

When the switch of the wavemeter is thrown

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for determination of the wavelength of a distant transmitter, whose signals are being received, a buzzer is connected into the circuit and the telephones and crystal detector are disconnected. The wavemeter in this state becomes a small transmitting set and the coil of the wavemeter is placed in inductive relation to the coils of the receiving set in the station. The receiver is then tuned in the usual manner to the wavelength of the incoming signal, and then the buzzer in the wavemeter set into operation by pressing a button on the wavemeter. This starts the miniature transmitter in the wavemeter sending out a feeble wave. The variable condenser in the wavemeter is then rotated until the sound of the buzzer is heard loudest in the receiving set. When this is done the wavemeter, the receiving set, and the distant transmitting set are all tuned to the same wavelength, and this wavelength can be read off the scale of the wavemeter variable condenser. There is a pointer on the variable condenser which points out the correct reading as the condenser is rotated. The Galvanometer is sometimes used instead of the crystal detector and telephones.

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Now you can see how easy it is for the radio inspector to check up on your wavelength, and you had better watch out that your transmitting wavelength is within lawful limits.

A grid leak may be made by cutting a piece of cardboard into a piece about one inch square, and then covering it with a uniform layer of india ink. After it has dried, cut this piece in half and bore two holes in one of the pieces one half an inch apart. In these holes insert brass 6-32 machine screws, flat-headed, and fasten them tight with nuts on the other side. One screw will be the one terminal and the other screw will be the other terminal of the grid leak while the india ink will form the resistance. This resistance may be varied by cutting the strip narrower and narrower while listening after each cutting to see if the signals are getting weaker or stronger with the changes in resistance. A record can be kept of the different widths and then when the maximum results are recorded and further cutting begins to decrease the strength of signals, the second piece of cardboard can be cut to the correct size and the grid leak connected to the set for permanent use. The grid leak can either be

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connected across the grid condenser or from the grid of the tube to the negative filament connection.

When the novice starts tuning a new regenerative receiver he usually gets all kinds of squeals, squawks, and grunts but no signals, and then he blames it on the receiver. He goes back to the manufacturer and complains that he has been cheated. He claims that the thing does not work, did not work, and never will work. The set is then tried out by the manufacturer or dealer and found to be satisfactory, and the dealer then says he will not take it back, and so on. The trouble in nine out of ten cases lies with the purchaser. Not that it is wholly his fault, but he either does not rig up the set correctly or does not understand how to operate it. Most of the howling, squealing noises are caused by the novice operator turning the regeneration dial around so far that the detector vacuum tube starts to oscillate and produce oscillations that combine with the incoming signals and start a squeak. Learn to operate your set before you pronounce it "No Good." Invite some friend, or some friend's child who does understand radio and the operation of the

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radio sets, and have them show you, and give you a few lessons in tuning.

It is certain that you would never think of purchasing an automobile and getting in and starting to drive the thing home if you did not know how to drive. You surely would not think of fooling with the levers and switches on the car in the hope that you would pull one or push one that would start the car on the way homeward. This would be foolishness.

Then do not expect to get results from your radio set until you understand at least what the different knobs are for, and have had a little practice tuning in the different wavelengths. "Practice makes perfect" in radio as in everything else.

We read every day in the papers and in some of the magazines articles on "How the Policemen of Chicago All Carry Radio Sets on Their Arms," "She Wears a Radio Set on Her Garter so She Can Always Set Her Watch by Radio" (with illustrations), and so forth. Of course, these things will be possible some day, when amplifying apparatus is further perfected and simplified, but do not make the mistake of taking these reports as meaning that just as good

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results can be obtained with miniature antennae, miniature receivers, or any other kind of portable apparatus which has been pictured in the papers and other publications as novelties. Remember that loop antennae, antennae of small sizes, antennae strung around the edge of an umbrella, antennae in or on automobiles, indoor antenna, bedspring antennae, resonance coil antennae, or any other variety of antenna in a miniature form will not bring in as loud signals as the regular garden variety of outside elevated antenna. Most of them will not even function without the aid of many steps of amplification. Of course the loop and the resonance coil will and do have their place and usefulness but for ordinary use the good old elevated wires will bring in louder signals for the amount of money spent than any of the newer "novel" types of antennae.

This has been written with no idea of discouragement to the amateur who is beginning in radio, but to help him get the facts fixed firmly in his mind so that he will know what he can expect at the present time and what he should not expect.

As stated before it probably will be a com-

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paratively short time before someone hits on a brilliant new scheme for simpler amplification which will at once make these dreamed-of things possible, but as yet they are novelties.

There is nevertheless a great field for the amateur to experiment in and it is never too late, and besides there is a whole lot of educational value to be gotten out of the subject, not to say anything of the pleasure that will be derived from adopting the subject of radio as a "hobby."

As a parting reminder to this chapter, let us remember that when we put up a set for receiving we should take the following precautions to get the best results:

First, decide from which direction the receiving is to be done mostly. Point the antenna in this direction. This is done by stringing the wires so that they point at the transmitting station, and taking off the lead in at the end closest to this station.

Second, see that the antenna is well insulated and not shielded any more than absolutely necessary by high buildings or other structures or by trees. All joints should be soldered.

Third, be sure that you have a good ground,

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Form 773 a.

DEPARTMENT OF COMMERCE

BUREAU OF NAVIGATION

RADIO SERVICE

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A . —	Period . . . . .
B — . . .	Semicolon — . — . — .
C — . — .	Comma . — . — . —
D — . .	Colon — — — . . .
E .	Interrogation . . — — . .
F . . — .	Exclamation point — — . . — —
G — — .	Apostrophe . — — — — .
H	Hyphen — . . . —
I . .	Bar indicating fraction — . . — .
J . — — —	Parenthesis — . — — . —
K — . —	Inverted commas . — . . — .
L . — . .	Underline . . — — . —
M — —	Double dash — . . . —
N — .	Distress Call . . . — — — . . .
O — — —	Attention call to precede every transmission — . — . —
P . — — .	General inquiry call — . — . — — — . —
Q — — . —	From (de) — . . .
R . — .	Invitation to transmit (go ahead) — . —
S . . .	Warning—high power — — . . — —
T —	Question (please repeat after.....)— interrupting long messages . . — — . .
U . . —	Wait . — . . .
V . . . —	Break (Bk.) (double dash) — . . . —
W . — —	Understand . . . — .
X — . . —	Error . . . . .
Y — . — —	Received (O. K.) . — .
Z — — . .	Position report (to precede all position messages) — . — .
Ä (German) . — . —	End of each message (cross) . — . — .
Á or Å (Spanish-Scandinavian) . — — . —	Transmission finished (end of work) (conclusion of correspondence) . . . — . —
CH (German-Spanish) — — — —	
É (French) . . — . .	
Ñ (Spanish) — — . — —	
Ö (German) — — — .	
Ü (German) . . — —	
1 . — — — —	
2 . . — — —	
3 . . . — —	
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6 —	
7 — — . . .	
8 — — — . .	
9 — — — — .	
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attached to the water pipes or gas pipes or both.

FOURTH, if the installation is to be permanent, be sure to prepare adequate lightning protection.

FIFTH, see that the set is hooked up correctly, and the batteries all charged and connected up in the right places with the polarity in the right direction.

SIXTH, make sure that the detector is adjusted for sensitiveness; in the case of the crystal, adjust the little spring against the crystal. In the case of the vacuum tube see that the filaments are lighted to the correct degree of brilliancy.

SEVENTH, be sure that you have a general understanding of how the tuning is done and where the settings should be placed to hear a certain wavelength signal. This is best learned by practice, but it is well to have a few lessons from some friendly amateur who will deem it an honor to help you.

If these precautions are taken the author is sure you will enjoy yourselves with radio and if you do he will be pleased to think that this little book has done a little good toward "Helping Everyone to Understand the Radio-Telephone."

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U. S. NAVY TIME SIGNALS.

Station	Call letters	Wave lengths (meters)	Range (miles)	K.W.	Wave	Type sent 75 merid.
Arlington ..	NAA	2500	600	100	Spark	Daily at 11.55 a. m. to Noon and 9.55 p. m. to 10 p. m.
Annapolis ...	NSS	16900	5000	400	Arc	Daily at 11.55 a. m. to Noon and 9.55 p. m. to 10 p. m.
Key West ...	NAR	1988	300	25	Spark	Daily 11.55 a. m. to Noon.
New Orleans.	NAT	1832	300	5	Spark	Daily 11.55 a. m. to Noon.
Balboa	NBA	10110	3000	100	Arc	Daily 4.55 to 5.00 a. m.; 12.55 to 1.00 p. m.
Colon	NAX	1620	300	5	Spark	Daily 4.55 to 5.00 a. m.; 12.55 to 1.00 p. m.
Cavite	NPO	12100	4000	250	Arc	Daily 8.55 to 9 a. m.; 9.55 to
		2700	300	10	Spark	10 p. m.
North Head, Wash.	NPE	2700	450	5	Spark	Daily 14.55 to 15.00 hr.
Eureka, Cal. .	NPW	2150	300	5	Spark	Daily 14.55 to 15.00 hr.
San Diego,	NPL	9800	3000	250	Arc	Daily (except Sundays and holi-
Calif.		1988	300	5	Spark	days) 14.55 to 15 hr.
San Francisco,	NPH	1650	1000	100	Arc	Daily (except Sundays and holi-
Calif.		1908	300	10	Spark	days) 14.55 to 15 hr.

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GREAT LAKES.	NAJ	1988	300	5	Spark	Daily (except Sundays and holidays) 11.55 to 12 hr.
PEARL HARBOR	NPM	11500	4000	250	Arc	Daily 18.55 to 19 hr.
		2250	300	10	Spark	

NOTE: The lag from the Naval Observatory to Arlington is 0.09 sec.
The lag from the Naval Observatory to Annapolis is 0.08 sec.
The lag from the Naval Observatory to Key West is 0.28 sec.

ANNAPOLIS, ARLINGTON, KEY WEST } Radio operated by the Naval Observatory clock by direct wire.

NEW ORLEANS, GREAT LAKES } Radio operated by the Naval Observatory clock via Western Union wires.

BALBOA, COLON } Darien has a transmitting clock and a break-circuit chronometer. Signals are received by radio from Annapolis or other stations that can be heard.

CAVITE, PEARL HARBOR } Intercepts radio and sends out own signal.

NORTH HEAD, EUREKA, POINT ARGUELLO, SAN DIEGO, SAN FRANCISCO } Mare Island sends through these radio stations via Western Union wires.

NOTE: Point Arguello has been discontinued.

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LIST SHOWING HOW RADIO CALL LETTERS ARE DIVIDED BETWEEN THE NATIONS OF THE WORLD

AAA to AMZ..Germany.
ANA to APZ..Dutch Indies.
AQA to AWZ..Norway.
AXA to AZZ..
B.....Great Britain.
CAA to CEZ..Chile.
CFA to CKZ..Great Britain and protectorates.
CLA to CMZ..Spain.
CNA to CNZ..Morocco.
COA to COZ...Great Britain.
CPA to CPZ...Bolivia.
CQA to CQZ...Monaco.
CRA to CUZ..Portugal and possessions.
CVA to CVZ..Roumania.
CWA to CWZ..Uruguay.
CXA to CXZ..Spain.
CYA to CZZ...Mexico.
D.....Germany.
EAA to EHZ..Spain and colonies.
EIA to EZZ..Great Britain.
F.....France and colonies.
G.....Great Britain.
HAA to HAZ..Hungary.
HBA to HBZ..Switzerland.
HCA to HCZ..Ecuador.
HDA to HEZ..Netherlands.
HFA to HFZ..Kingdom of Serbia.
HGA to HHZ..Siam.
HIA to HIZ...Dominican Republic.
HJA to HKZ..Republic of Columbia.
HLA to HNU..Spain.
HNV to HNZ..New Hebrides.
HOA to HZZ..France and colonies and protectorates.
I.....Italy and colonies.
J.....Japan and colonies.
KAA to KBZ..Germany.
KCA to KCZ..Latvia.
KDA to KZZ..United States.
LAA to LHZ..Norway.
LIA to LRZ..Argentine Republic.
LSA to LUZ..Great Britain.
LVA to LVZ..Guatemala.
LWA to LWZ..Norway.
LXA to LZZ..Bulgaria.
M.....Great Britain.
N.....United States.
OAA to OBZ..Peru.
OCA to OFZ..Great Britain.
OGA to OIZ...Denmark.
OJA to OJZ...Finland.
OKA to OKZ..Czechoslovakia.
OLA to OMZ..Netherlands.
ONA to OTZ..Belgium and colonies.
OUA to OZZ..Denmark.
PAA to PIZ...Netherlands.
PJA to PJM..Curacao.
PJN to PJZ..Surinam.
PKA to PMZ..Dutch Indies.
PNA to PPZ..Brazil.
PQA to PSZ...Portugal.
PTA to PVZ..Brazil.
PWA to PWZ..Cuba.

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RADIO CALL LETTERS

PXA to PZZ.. Netherlands.
Q..... Reserved for code abbreviations.
R..... Russia.
SAA to SMZ.. Sweden.
SNA to STZ... Brazil.
SUA to SUZ.. Egypt.
SVA to SZZ... Greece.
TAA to TEZ.. Turkey.
TFA to TFZ.. Iceland.
TGA to THZ.. Greece.
TIA to TOZ... Spain.
TPA to TUZ.. Norway.
TVA to TZZ... Netherlands.
UAA to UMZ.. France and colonies and protectorates.
UNA to UNZ.. Kingdom of Serbia.
UOA to UOZ.. Austria.
UPA to UZZ.. Italy.
VAA to VGZ.. Canada (British).
VHA to VKZ.. Australia (British).
VLA to VMZ.. New Zealand (British).
VNA to VNZ.. South African Union (British).
VOA to VOZ.. Newfoundland (British).
VPA to VSZ.. British colonies not autonomous.
VTA to VWZ.. British India.
VXA to VZZ.. Colonies and protectorates of Great Britain.
W..... United States.
XAA to XDZ.. Mexico.
XEA to XMZ.. Great Britain.
XNA to XSZ... China.
XTA to XZZ.. Great Britain.
Y..... Great Britain.
Z..... Great Britain.

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FORM 772 a

DEPARTMENT OF COMMERCE

BUREAU OF NAVIGATION

RADIO SERVICE

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION	QUESTION	ANSWER OR NOTICE
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?....	This is .....
QRB	What is your distance?	My distance is .....
QRC	What is your true bearing?.....	My true bearing is.....degrees.
QRD	Where are you found for?	I am bound for.....
QRF	Where are you bound from?	I am bound from.....
QRG	What line do you belong to?.....	I belong to the.....Line.
QRH	What is your wave length in meters?..	My wave length is.....meters.
QRJ	How many words have you to send?..	I have.....words to send.
QRK	How do you receive me?.....	I am receiving well.
QRL	Are you receiving badly? Shall I send 20? . . . — . for adjustment?.....	I am receiving badly. Please send 20. . . . — . for adjustment.
QRM	Are you being interfered with?.....	I am being interfered with.
QRN	Are the atmospherics strong?.....	Atmospherics are very strong.

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QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?.....	I have nothing for you.
QRV	Are you ready?	I am ready. All right now.
QRW	Are you busy?	I am busy (or: I am busy with.....). Please do not interfere.
QRX	Shall I stand by?.....	Stand by. I will call you when required.
QRY	When will be my turn?.....	Your turn will be No. .....
QRZ	Are my signals weak?	Your signals are weak.
QSA	Are my signals strong?	Your signals are strong.
QSB	Is my tone bad?	The tone is bad.
	Is my spark bad?	The spark is bad.
QSC	Is my spacing bad?	Your spacing is bad.
QSD	What is your time?.....	My time is .....
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG	.....	Transmission will be in series of 5 messages.
QSH	.....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for.....?....	Collect .....
QSK	Is the last radiogram canceled?.....	The last radiogram is canceled.
QSL	Did you get my receipt?.....	Please acknowledge.
QSM	What is your true course?.....	My true course is.....degrees.

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ABBREVIATIONS USED IN RADIO COMMUNICATION (*continued*)

QSN	Are you in communication with land?	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with.....)?	I am in communication with..... (through.....).
QSP	Shall I inform.....that you are calling him?	Inform.....that I am calling him.
QSQ	Is.....calling me?	You are being called by.....
QSR	Will you forward the radiogram?.....	I will forward the radiogram.
QST	Have you received the general call?.....	General call to all stations.
QSU	Please call me when you have finished (or: at.....o'clock)?	Will call when I have finished.
*QSV	Is public correspondence being handled?	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency?..	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?..	Decrease your spark frequency.
QSY	Shall I send on a wave length of..... meters?	Let us change to the wave length of..... meters.
QSZ	.....	Send each word twice. I have difficulty in receiving you.
QTA	.....	Repeat the last radiogram.
QTE	What is my true bearing?	Your true bearing is ..... degrees from.....
QTF	What is my position?	Your position is.....latitude..... longitude.

* Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

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"A" Battery.—The battery used to light the filament of the vacuum tube which liberates electrons that flow over to the plate and cause the tube to function.

Absorption modulation.—A system employing a single loop of wire around the transmitting inductance, across which a microphone is connected which permits the outgoing waves to be modulated in accordance with sounds impressed on the microphone diaphragm.

Aerial.—See *Antenna.*

Alternating current.—A current that changes its direction, running first one way through a circuit and then reversing itself and running in the opposite direction. These changes in direction occur a definite number of times per second.

Ammeter.—An electrical instrument for measuring the rate of flow of an electric current through a circuit.

Ampere.—The unit of electric current.

Amplification.—Increasing the strength of incoming signals by the use of an amplifier.

Amplifying telephones.—Head telephones which increase the volume of sound to a greater extent than that obtained with the ordinary telephones.

Amplifying transformer.—A coupling transformer used between the successive steps of amplification in a receiving set which steps up the voltage in the preceding step and supplies the increased voltage to the grid of the following tube, thus amplifying the signals.

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Amplitude.—A curve which shows the peak or maximum values of current impulses or voltages.

Antenna.—The aerial wires which are used to collect by induction the energy necessary to operate the receiving set.

Antenna resistance.—See *Radiation resistance.*

Antenna wire.—The wire used for the elevated aerial or antenna. Usually a bare No. 14 stranded copper wire is used.

Arc.—The arc is an electric current passing through a gas. A continuous wave can be generated by means of an arc with associated apparatus whereby long distance telegraphic and telephonic communication is made possible without the use of wires.

Armature.—The rotating part of a generator in which the currents are induced by magnetic action.

Atmospherics.—See *Static.*

Atom.—The smallest division of matter which remains in the form of matter.

Audibility.—The strength of sound impulses.

Audibility meter.—An electrical instrument that measures the strength of radio signals.

Audio frequency transformer.—A transformer which responds to impulses whose frequency lies within the audible range.

Audion.—See *Vacuum tube detector* and *Vacuum tube amplifier.*

Audio frequency.—Oscillations having a frequency that lies within the range of frequencies that the human ear can hear.

Auto transformer.—A transformer that may be used for stepping up voltages or stepping down voltages, which is directly coupled, having only a single winding.

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"B" battery.—The battery used on the plate of the vacuum tubes which places a positive charge on the plate which causes the tube to function properly.

Bakelite.—An insulation used in radio apparatus which is formed of a base of a synthetic resin.

Bank wound coil.—A coil that is wound in banks or layers.

Battery.—A chemical cell that produces or stores up energy that can be released in the form of an electric current.

Binding post.—A convenient form of connection employed for connecting batteries and other instruments to the radio apparatus.

Broadcasting.—Transmitting news, lectures and music to the general public for their pleasure and education, via radio.

Bulb.—See *Vacuum tube.*

Buzzer.—An electrical instrument that has a vibrator which is set into motion when an electric current is passed through it. The buzzer is a generator of oscillations.

Cage antenna.—This form of antenna uses a number of wires arranged in the shape of a cylindrical cage. It is very efficient for both receiving and transmitting.

Capacity.—The electrical capacity of a circuit is the measure of the electrostatic energy that can be stored up in the circuit. The unit of capacity is the farad, but the microfarad is the division of the farad used in radio for measurements.

Carborundum crystal.—A mineral crystal used as a detector for rectifying feeble high frequency currents.

Choke coil.—A coil used to prevent alternating currents from flowing through a circuit. High frequency choke coils have an air core while low frequency chokes are wound on an iron core.

Code.—A telegraphic code which contains characters com-

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posed of groups of dots and dashes, by means of which communication may be carried on by radio telegraph.

Coherer.—One of the earlier types of radio detectors, not in modern use.

Coil.—See *Inductance.*

Commutator.—The rotating contact-making device on a generator or motor.

Condenser.—An electrical instrument for storing up electrical energy in the form of electrostatic charges.

Connections.—The wires used to connect up the instruments in a radio set.

Constant current modulation.—See *Heising modulation.*

Continuous wave.—A series of electrical oscillations in which the amplitude of each oscillation remains constant, and the oscillations continue without interruption.

Core.—That part of a coil that occupies the space inside the cylinder formed by the coil winding.

Counterpoise ground.—A type of ground system in which the wires that form the "ground" are insulated from the ground. This type of ground system functions through the capacity effect of the wires to the ground rather than the conventional method of using a direct electrical connection to the ground.

Coupler.—Two coils which are associated inductively to transfer energy received from an antenna to the detector circuit in a radio receiver.

Coupling.—The method used for transferring energy from one circuit to another in a radio set.

Crystal detector.—Certain minerals possess the ability to conduct currents in one direction only and these are used to rectify high frequency currents used in radio

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and turn them into direct current impulses so that they may be used to operate the telephones.

Detector.—See *Crystal Detector* and *Vacuum Tube Detector.*

Diaphragm.—The vibrating disc in the telephone that in combination with the magnets, converts the electrical energy into sound waves.

Dielectric.—See *Insulator.*

Direct current.—A current that flows continuously through a circuit in one direction.

Directional effect.—Most types of antennae transmit and receive better in one direction than in other directions. This phenomenon is called the *Directional effect of the antenna.*

Direction finder.—Radio apparatus which in combination determines the direction from which radio signals emanate.

Dry cell.—A type of portable battery generating approximately 1½ volts per cell.

Dummy antenna.—See *Phantom antenna.*

Edison effect.—The discovery that a heated filament in a vacuum gave off electrons, was called the Edison effect, because Edison made the discovery.

Edison storage battery.—A battery that may be recharged. This type of battery uses an alkaline electrolyte, a little less than 1½ volts per cell.

Electrolyte.—The solution with which a battery is filled.

Electrolytic detector.—An early form of radio detector, not used to-day.

Electromagnet.—An instrument which comprises a core and a winding. When an electric current is passed through the winding, an electromagnetic field is set up in its vicinity.

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Electromagnetic field.—The field set up around a magnet or electromagnet.

Electron.—The smallest charge of electricity.

Electron tube.—See *Vacuum tube.*

Electrostatic field.—The stress set up between the plates of a condenser, when the condenser is "charged."

E.M.F.—Electromotive force, measured in volts. See *Voltage.*

Fan type antenna.—Elevated wires arranged in the shape of a fan.

Farad.—The unit of electrostatic capacity.

Field rheostat.—The variable resistance which is used to control the current flowing through the field windings of a motor or generator.

Filament.—The fine wire inside a vacuum tube which is heated by passing a current of electricity through it, thus releasing a stream of electrons from the filament.

Filament lighting transformer.—A transformer used to heat the filaments of transmitting vacuum tubes. Not used for receiving tubes, as the alternating current would cause a loud hum in the receiving set.

Filter circuit.—A special circuit composed of choke coils and condensers that prevent alternating currents from flowing through the circuit to which the filter circuit is attached, but which offer little or no resistance to the path of a direct current.

Fixed condenser.—An electrical instrument which is used to hold a charge of electricity and which has a fixed value of capacity.

Flat top antenna.—An antenna in which the elevated wires are supported horizontally in regard to the earth's surface, with a vertical lead in wire running down to the instruments.

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Frequency.—The number of cycles per second occurring in an alternating current.

Frequency meter.—An electrical instrument which measures the frequency of an alternating current in cycles per second.

Galena crystal.—A mineral crystal used for rectifying the high frequency impulses received in a radio receiving set. This is probably the most sensitive of all the crystals used for this purpose.

Galvanometer.—An electrical instrument for measuring very feeble currents.

Generator.—A machine for producing electric currents.

Grid.—One of the elements of the vacuum tube which is used to control the electron stream flowing from the filament to the plate.

Grid condenser.—A small fixed condenser connected in series with the grid of the vacuum tube to charge the grid to the correct potentials.

Grid leak.—A resistance connected from the grid of the vacuum tube to the filament to prevent too high voltage from collecting on the grid and thus "choking up" the tube and causing it to cease functioning properly.

Grid modulation.—A method of molding the outgoing waves from a radio telephone transmitter into the form of the impressed sound waves, by means of control of the grid voltage of the oscillator tube.

Ground.—The ground in a radio set is that connection that is used to connect one side of the radio set to earth.

Guy wires.—The ropes or wires used to hold up the mast which is sometimes used to support the antenna.

Heising modulation.—A form of modulation that uses an additional modulator vacuum tube in combination with other apparatus for molding the input to the vacuum

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tube oscillator into the shape of the impressed sound waves.

Henry.—The unit of inductance.

Hertzian wave.—The wave motion through space that makes radio possible. Discovered by Hertz.

Hookup.—A diagram of connections for a radio set.

Hot wire meter.—An electrical instrument for measuring current.

Hydrometer syringe.—An instrument for measuring the specific gravity of the electrolyte of a storage battery, thus determining its electrical condition.

Impedance.—The electrical opposition of a circuit to an alternating current.

Inductance.—A coil of wire.

Induction coil.—Same as a spark coil used on an automobile.

Insulator.—A material that will not pass an electrical current.

Interrupter.—A make and break device for breaking up a direct current into impulses, such as the vibrator on a spark coil.

Key.—The instrument that is used in radio telegraphy for sending out the code in dots and dashes.

Kick back preventor.—A device which prevents the high frequency currents generated in a transmitting station from leaking back on the power lines and burning out the generator or wiring.

Kilowatt.—1000 watts.

L antenna.—A flat top antenna in which the elevated wires and the lead in wires form a shape like the letter L inverted.

Lead battery.—A type of storage battery that is generally used for furnishing the current for lighting the fila-

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ments of receiving vacuum tubes. This battery contains an acid electrolyte.

Lead in.—The wires that run down from the antenna to the instruments are called the lead in wires.

Lightning switch.—A switch installed outside the window to protect the radio apparatus and the house during an electrical storm.

Loading coil.—An inductance or coil for increasing the wave length of a radio set. This does not increase the distance range.

Loop antenna.—A portable coil antenna.

Loudspeaker.—A device for making the received radio signals audible throughout an entire room or house without the use of head telephones.

Magnet.—A piece of steel that has been magnetized and is capable of attracting other magnetic objects in its vicinity.

Magnetic.—Anything is magnetic that is attracted to a magnet.

Magnetic detector.—An obsolete form of radio detector invented by Marconi.

Magnetic modulation.—Molding the output of a radio telephone transmitter into the shape of impressed sound waves by means of a special magnetic transformer.

Meter.—The unit of length. Wavelength is measured in meters.

Microphone transmitter.—The device which is used to convert the sound waves into electrical impulses.

Milliampere.—One-thousandth part of an ampere. See *Ampere.*

Modulation.—Molding the high frequency currents generated by the vacuum tube transmitter into the shape of the sound waves, thus making possible radio-telephony.

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Modulation transformer.—A transformer which is used in some of the various methods of modulation.

Motor generator.—A combination of a motor and a generator which is used to generate currents.

Negative.—See *Polarity.*

Non-conductor.—See *Insulator.*

Nucleus.—The center or attracting force which binds the atoms together.

Ohm.—The unit of resistance.

Oscillation.—A reversal of current flowing through a circuit.

Oscillation transformer.—A coupling transformer for transferring energy from one circuit to another in a transmitting set.

Permanent magnet.—A magnet that has been permanently magnetized.

Phantom antenna.—A substitute antenna for tuning a transmitting set, composed of a condenser, a resistance, and an inductance which can be varied to simulate the electrical characteristics of a real antenna.

Plate.—One of the elements of the vacuum tube which is used to collect the electrons, flowing across from the filament.

Plate current.—The current flowing in the plate circuit of a vacuum tube.

Plate voltage.—The voltage applied to the plate by special "B" batteries to keep the plate positive so that it will attract the electrons flowing across from the filament.

Polarity.—The current flows out of a battery from the positive pole and around through the circuit and into the battery again at the negative pole.

Poles.—The terminals of a battery, usually marked Positive (+) and Negative (−).

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Positive.—See *Polarity.*

Potential.—See *Voltage.*

Potentiometer.—A resistance device which is used to control voltage.

Printing telegraph recorder.—An instrument that prints and records messages sent in code.

Quenched spark gap.—The most efficient type of spark gap. The spark discharge takes place in a number of vacuum chambers placed in series.

Radiation.—A disturbance created in the vicinity of a transmitting antenna that spreads in the form of a circular wave motion.

Radiation resistance.—The impedence of an antenna at a definite wavelength.

Radio frequency amplifier.—A vacuum tube amplifier that amplifies at a radio frequency.

Radio goniometer.—See *Direction finder.*

Radiophone.—See *Radio-telephone.*

Radio-telephone.—A radio transmitting and receiving set that transmits and receives voice and music.

Receiving set.—A radio set that tunes, detects, and makes audible the impulses transmitted from a distant transmitting set.

Rectifier.—A device for converting an alternating current into a direct current.

Regeneration.—A circuit employed with the vacuum tube detector whereby the currents are fed back through the tube or a suitable coupling from the plate circuit to the grid circuit, thus causing a great degree of amplification to take place without additional amplifiers.

Relay.—An automatic electrically operated switch which can operate on very small currents and control larger currents, by opening or closing contacts, thus operating

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machinery at a distance. The vacuum tube is a relay in a sense.

Resonance.—Electrical balance. When the capacity reactance is equal and opposite to the inductance reactance, the circuit is "in resonance" at a given frequency.

Resonance coil antenna.—A coil antenna which has a natural period, with one end left open, of the wavelength which it is designed to receive on.

Resistance.—The opposition offered by a circuit to a direct current. Resistance is measured in Ohms.

Rheostat.—A variable resistance coil.

Rotary spark gap.—A spark gap which has a number of rotating electrodes which at certain intervals come opposite to stationary electrodes, thus allowing a spark to jump the intervening gap. This gap is used to raise the spark frequency of a telegraph transmitter.

Round's round ground.—A series of buried plates arranged edge to edge in a circle.

Selectivity.—Sharpness of tuning.

Signal.—Transmitted or received impulses.

Silicon.—A mineral crystal used for rectifying the received high frequency impulses.

Slider.—Adjustable contact attached to a tuning coil for cutting in or out any number of turns on the coil.

Socket.—Base for the vacuum tube.

Solder.—For obtaining sure connections in the radio set all joints should be "soldered" or "sweated" together with molten lead and tin. This combination of metals is called solder.

Spaghetti.—A varnished cambric tubing insulation. Gets its name because it resembles spaghetti in appearance.

Static.—Atmospheric electricity.

Storage battery.—See *Lead battery* and *Edison battery.*

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Straight spark gap.—A stationary open spark gap consisting of two fixed electrodes mounted on a base between which a spark may jump. The distance between the electrodes may be adjusted.

Switch.—A device for opening or closing an electric circuit.

Switch lever.—The contact-making arm of a switch.

T Antenna.—An antenna with a horizontal portion, with the lead in wires attached in the middle of the horizontal wires giving the antenna the general shape of the letter T.

Tap.—A switch point or pole.

Telegraphy.—Communication by means of a dot and dash code.

Telephone condenser.—A small fixed condenser usually connected across the telephone receivers.

Telephone jack.—A receptacle into which the telephone plug is inserted to make connection between the receiver and the telephones.

Telephone plug.—A contact-making device fastened on the end of the telephone cords or wires, which may be inserted into the telephone jack, to make connection with the receiving set.

Telephone receiver.—A device for converting electrical energy into sound waves.

Telephony.—Communication by means of voice waves or electrical waves molded into the shape of voice waves.

Terminal.—A connecting device or binding post.

Tickler.—The coil or coupling device that is used to control the amount of current fed back from the plate circuit to the grid circuit in a regenerative set.

Time signals.—Government radio stations send out time

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signals that enable listeners in all parts of the country to set their clocks to the correct time.

Tone wheel.—A rotating commutator for breaking up a current into any desired audio frequency.

Transformer.—An electromagnetically operated device for transferring electrical energy from one circuit to another.

Transmitting set.—A radio set for sending signals without the use of wires.

Tuner.—An instrument for tuning the receiver to any desired wavelength.

Tungar rectifier.—A device for changing an alternating current to a direct current for charging batteries.

Tuning coil.—A tuner consisting of a single coil.

Umbrella antenna.—An antenna with the elevated wires radiating like the ribs of an umbrella.

Vacuum tube.—See *Vacuum tube detector, Vacuum tube amplifier,* and *Vacuum tube oscillator.*

Vacuum tube amplifier.—A tube used for amplifying signals.

Vacuum tube detector.—A tube used for rectifying the incoming high frequency impulses in a receiving set. This is the most efficient type of detector known.

Vacuum tube oscillator.—A tube used for producing high frequency currents whereby present day radio-telephony is made possible.

Variocoupler.—A combination tuning and coupling device used in receiving.

Variometer.—A continuously variable inductance.

Volt.—The unit of potential.

Voltage.—The pressure which causes an electrical current to flow through a circuit.

Voltmeter.—An electrical instrument for measuring voltage.

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Wattmeter.—An electrical instrument for measuring the power in a circuit. The length in meters of a radio wave from crest to crest.

Wavemeter.—An electrical instrument for measuring wavelength.

Winding.—A coil of wire.

Wireless.—The former name for radio.

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